APPENDIX D:

ENVIRONMENTAL IMPACTS OF CONTINUED CYLINDER STORAGE AT CURRENT STORAGE SITES

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The following is a list of acronyms and abbreviations, including units of measure, used in this document. Some acronyms used only in tables are defined in those tables.

ACRONYMS AND ABBREVIATIONS

General

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
K_d	distribution coefficient
LCF	latent cancer fatality
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
LMES	Lockheed Martin Energy Systems, Inc.
MCL	maximum contaminant level
MEI	maximally exposed individual
NRC	U.S. Nuclear Regulatory Commission
PEIS	programmatic environmental impact statement
PM_{10}	particulate matter with a mean diameter of 10 µm or less
ROI	region of influence
VOC	volatile organic compound

Chemicals

CO	carbon monoxide
HC	hydrocarbon
HF	hydrogen fluoride
NO_x	nitrogen oxides
SO_x	sulfur oxides
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2F_2	uranyl fluoride

UNITS OF MEASURE

ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
gal	gallon(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
μg	microgram(s)
μm	micrometer(s)
m	meter(s)
m^3	cubic meter(s)
mg	milligram(s)
min	minute(s)
mrem	millirem(s)
pCi	picocurie(s)
ppb	part(s) per billion
ppm	part(s) per million
rem	roentgen equivalent man
s	second(s)
yd^2	square yard(s)
yd^3	cubic yard(s)
yr	year(s)

APPENDIX D:

ENVIRONMENTAL IMPACTS OF CONTINUED CYLINDER STORAGE AT CURRENT STORAGE SITES

The U.S. Department of Energy (DOE) is proposing to develop a strategy for long-term management of the depleted uranium hexafluoride (UF_6) inventory currently stored at three DOE sites near Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. This programmatic environmental impact statement (PEIS) describes alternative strategies that could be used for the long-term management of this material and analyzes the potential environmental consequences of implementing each strategy for the period 1999 through 2039. This appendix provides detailed information describing continued storage of DOE-generated cylinders at the three current storage sites. The discussion provides background information, as well as a summary of the estimated environmental impacts associated with this option.

> **Continued Storage of Cylinders**
>
> The continued storage of depleted UF_6 cylinders at the Paducah, Portsmouth, and K-25 sites would be required for some period of time for all alternative management strategies. Continued storage would involve maintenance of the cylinders — including inspections, painting, and cylinder yard upgrades — as well as valve replacement and cylinder repair, as needed. The impacts of continued storage were assessed separately for the following:
>
> **No Action Alternative:** Potential impacts were assessed for continued storage of the entire cylinder inventory at the three current storage sites through the year 2039, including potential long-term impacts to groundwater and human health and safety.
>
> **Action Alternatives:** Potential impacts were assessed for continued storage at the three current storage sites based on the assumption that the number of cylinders at these sites would begin to decrease in the year 2009 and that all of the cylinders would be removed from the three sites by the end of the year 2028 (corresponding to the period during which conversion or long-term storage would be implemented). Potential long-term impacts were also assessed.

Continued cylinder storage at the Paducah, Portsmouth, and K-25 sites would be required for some period of time for all alternative management strategies. It was assumed that the entire depleted UF_6 cylinder inventory would continue to be stored at the three sites through 2008 for all alternatives. Under the no action alternative, the entire cylinder inventory would continue to be stored at the three sites indefinitely. For purposes of analysis and for comparison with action alternatives, the assessment period considered in this PEIS was through the year 2039. Under action alternatives, the number of cylinders stored at the three sites would decrease as the cylinders were transported to another location for conversion or long-term storage. This decrease at the sites was assumed to occur from 2009 through

2028.[1] The assessment of impacts from continued cylinder storage at the three sites considers all anticipated activities required to safely manage the cylinder inventory from 1999 through 2039 for the no action alternative and from 1999 through 2028 for the action alternatives. Potential long-term impacts from cylinder breaches potentially occurring at the sites through the year 2039 (No Action Alternative) or through 2028 (action alternatives) were estimated by calculating the maximum groundwater contamination levels possible in the future from those breaches.

The cylinder surveillance and maintenance activities that are to be undertaken from now through September 30, 2002, are described in detail in the *UF_6 Cylinder Project Management Plan* (Lockheed Martin Energy Systems [LMES] 1997d). However, because the assessment period for this PEIS extends through the year 2039, a set of assumptions was needed to define the activities for estimating the impacts of continued storage through 2039. The assumptions used are documented in a memo by J.W. Parks, Assistant Manager for Enrichment Facilities, DOE Oak Ridge Operations Office (Parks 1997). In developing these assumptions, it was recognized that the activities actually undertaken might differ from those described in the cylinder project management plan. Therefore, assumptions were chosen such that anticipated impacts of continued cylinder storage made in the PEIS would result in conservative estimates (that is, the assumptions used would overestimate impacts rather than underestimate them).

Impacts associated with the following activities were analyzed: (1) storage yard reconstruction and cylinder relocations; (2) routine and ultrasonic testing inspections of cylinders and valve monitoring and maintenance; (3) cylinder painting; and (4) repair and removal of the contents of any cylinders that might be breached during the storage period. Although actual activities occurring at the three storage sites during the time period considered might vary from those described in the cylinder project management plan, the estimated impacts of continued storage activities assessed in this PEIS are likely to encompass and bound the impacts at these sites. The assumptions for each activity are discussed further in the following paragraphs.

The total inventory of 46,422 depleted UF_6 cylinders generated by DOE before 1993 is currently stored as follows: 28,351 cylinders (about 60%) in 13 yards at the Paducah site; 13,388 cylinders (about 30%) in two yards at the Portsmouth site; and 4,683 cylinders (about 10%) in three yards at the K-25 site. An intensive effort is ongoing to improve yard storage conditions. This effort includes (1) relocation of some cylinders, which are currently either in contact with the ground or are too close to one another to allow for adequate inspections, and (2) construction of new storage yards or reconstruction of existing storage yards to provide a stabilized concrete base and monitored drainage for the cylinder storage areas. The impacts from planned relocation and construction activities that will not be complete by 1999 are included in the PEIS for consideration as part of continued cylinder storage; these activities include reconstruction of four Paducah yards, construction of a new yard for the K-25 site cylinders, relocation of about 19,000 cylinders at Paducah, and relocation of all cylinders at K-25.

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[1] These estimates were meant to provide a consistent analytical timeframe for the evaluation of all of the PEIS alternatives and do not represent a definitive schedule.

The stored cylinders are regularly inspected for evidence of damage or accelerated corrosion; about 75% are inspected every 4 years, and 25% are inspected annually. Annual inspections are required for those cylinders that have been stored previously in substandard conditions and/or those that show areas of heavy pitting or corrosion. In addition to these routine inspections, ultrasonic inspections are currently conducted on some of the relocated cylinders. The ultrasonic testing is a nondestructive method to measure the wall thickness of cylinders. Valve monitoring and maintenance are also conducted for cylinders that exhibit discoloration of the valve or surrounding area during routine inspections. Leaking valves are replaced in the field. Impacts from routine inspections, ultrasonic inspections, and valve maintenance are evaluated as components of continued cylinder storage. For assessment of the no action alternative, the frequency of routine inspections and valve monitoring was assumed to remain constant through 2039, and ultrasonic testing was assumed to be conducted annually for 10% of the relocated cylinders. Relocation activities would be completed in about 2003, after which 10% of the cylinders painted each year were assumed to be inspected by ultrasonic testing. For the action alternatives, the frequency of inspections was assumed to decrease with decreasing cylinder inventory (about a 5% decrease in inspections per year) from 2009 through 2028.

Current plans call for cylinder painting at the three sites to control cylinder corrosion. On the basis of information from the cylinder painting program (Pawel 1997), the analysis assumed that the paint would protect the cylinders for at least 10 years and that, once painted, the cylinders would not undergo further corrosion during that time. Although repainting might not actually be required every 10 years, the analysis assumed that every cylinder would be repainted every 10 years (except for the period 2019 through 2028 for the action alternatives, during which time no painting was assumed because of decreasing inventory size — i.e., cylinders being removed within 10 years for conversion or long-term storage elsewhere would not be repainted). The painting activity includes cylinder surface preparation (e.g., scraping and removal of rust deposits). Because some radioactive contaminants may exist on the surface of cylinders and because the metal content of the paints used previously are unknown, for purposes of the PEIS analysis the waste generated during surface preparation was considered to be low-level-mixed waste. Cylinder painting activities would be the primary source of potential radiological exposures for involved workers under the continued cylinder storage option.

Before 1998, seven breached cylinders had been identified at the three storage sites. Breached cylinders are cylinders that have a hole of any size at some location on the wall. Investigation of these breaches indicated that five of the seven were initiated by mechanical damage during stacking; the damage was not noticed immediately, and subsequent corrosion occurred at the damaged point. The other two cylinder breaches were concluded to have been caused by external corrosion due to prolonged ground contact. In 1998, one additional breached cylinder occurred during the course of cylinder maintenance operations. When cylinders are breached, moist air reacts with the exposed UF_6 and iron, resulting in the formation of a dense plug of uranium tetrafluoride (UF_4) and iron fluoride hydrates that prevents rapid loss of material from the cylinders. Further details on cylinder corrosion and releases due to breaches are given in Appendix B.

Considering the improved storage conditions in the yards, intensive inspection schedule, and the planned cylinder painting, the impact analysis for the no action alternative was based on the assumption that breaches resulting from corrosion would cease. Therefore, the primary potential cause of breaches considered for continued storage was mechanical damage occurring during cylinder handling (e.g., for painting or relocations). Although stringent inspection procedures are now in place to immediately identify and repair any cylinder breaches that might occur during handling, for purposes of analysis it was nonetheless assumed that breaches caused by mechanical damage would continue to occur at the same rate as in the past and that the breaches would go unidentified for a long enough time for releases to occur (see Appendix B). Using these assumptions, the total numbers of breaches assumed to occur from 1999 through 2039 for the no action alternative analyses (base case) were 36 for the Paducah site, 16 for the Portsmouth site, and 7 for the K-25 site.

The above breach numbers were used to estimate potential impacts from repairing breached cylinders and from releases that might occur during continued storage through 2039 under the no action alternative. Potential radiological exposures of involved workers could result from patching breached cylinders and subsequently emptying the cylinder contents into new cylinders. The impacts to groundwater and human health and safety from uranium releases were assessed by estimating the amount of uranium that could be transported from the yards in surface runoff, followed by estimating migration through the soil to the groundwater.

The uncertainty in both the effectiveness of painting in controlling further corrosion and in the future painting schedule was addressed by also conducting a conservative assessment based on the assumption that external corrosion was not halted by improved storage conditions and painting, resulting in more breaches (see Section D.3). Using these assumptions, the total numbers of breaches estimated from 1999 through 2039 were 444 for the Paducah site, 74 for the Portsmouth site, and 213 for the K-25 site. The results of this assessment were used to provide an estimate of the earliest time when continued cylinder storage could begin to raise regulatory concerns under these worst-case conditions.

For the action alternatives, continued storage at the three sites would occur through 2028, with the inventory decreasing by about 5% per year starting in 2009 until no cylinders would remain at the current sites in 2028. Because the status of a cylinder painting program is less certain for the action alternatives, the estimated number of breached cylinders for these alternatives was based on the assumption that external corrosion was not controlled by painting (see Appendix B for the specific number of breaches assumed and Section D.4 for discussion of potential impacts for the action alternatives).

For all hypothetical cylinder breaches, it was assumed that the breach would go undetected for a period of 4 years, which is the duration between planned inspections for most of the cylinders. In practice, cylinders that show evidence of damage or heavy external corrosion are inspected annually, so it is unlikely that a breach would go undetected for a 4-year period. On the basis of estimates from investigation of cylinder breaches that have occurred to date, 1 lb (0.45 kg) of uranium (in the form of uranyl fluoride [UO_2F_2]) and 4.4 lb (2 kg) of hydrogen fluoride (HF) were assumed to be released from each breached cylinder annually for a period of 4 years.

D.1 SUMMARY OF CONTINUED CYLINDER STORAGE IMPACTS

This section provides a summary of the potential environmental impacts associated with continued cylinder storage at the three current storage sites for the no action alternative and for the other alternatives. Additional discussion and details related to the assessment methodologies and results for each area of impact are provided in Sections D.2 and D.4. The potential environmental impacts of continued cylinder storage are summarized in Table D.1 and as follows:

- Through the year 2039 for the no action alternative and the year 2028 for the action alternatives, all health and safety impacts to workers and the general public in the vicinity of the sites as a result of cylinder storage and maintenance activities are estimated to be well within the applicable health and safety standards.

- All postulated accidents, including the highest consequence accidents, were estimated to result in zero latent cancer fatalities (LCFs) due to radiological causes among both workers and members of the general public. Some accidents, if they occurred, could result in up to 300 irreversible adverse effects among workers and 1 irreversible adverse effect among the general public due to chemical effects of released materials. However, such accidents have a very low probability and would not be expected to occur through the year 2039 for the no action alternative and the year 2028 for the action alternatives.

- During the assessment period (through 2039 under the no action alternative and 2028 under the action alternatives), all environmental impacts resulting from continued storage activities, including impacts to air resources, water resources, socioeconomics, ecological resources, waste management, land and other resources, cultural resources, and the environmental justice impacts would be negligibly small or well within the applicable standards.

- Long-term impacts from cylinder breaches estimated to occur through 2039 under the no action alternative would be well within the applicable standards assuming that cylinder painting would be effective in controlling corrosion. If no credit were taken for corrosion reduction through painting and continued maintenance, and on the basis of conservative estimates of numbers of breaches and material loss from breached cylinders, it is estimated that the uranium concentrations in the groundwater around the three sites would exceed the guideline of 20 µg/L used for comparison at some time in the future (around the year 2100 or later). Similarly, if the larger number of cylinder breaches occurred because of uncontrolled cylinder corrosion, air concentrations of HF at the K-25 site could exceed the State of Tennessee standard around the year 2020. For the action alternatives, all long-term impacts are estimated to remain within the guideline values with or without taking credit for reduced corrosion through painting.

TABLE D.1 Summary of Continued Cylinder Storage Impacts[a]

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Normal Operations: Radiological			
Involved Workers: Total collective dose (3 sites): 1,500 person-rem	**Involved Workers:** No impacts	**Involved Workers:** Total collective dose (3 sites): 720 person-rem	**Involved Workers:** No impacts
Total number of LCFs (3 sites): 0.6 LCF		Total number of LCFs (3 sites): 0.3 LCF	
Noninvolved Workers: Maximum annual dose to MEI : 0.043 – 0.11 mrem/yr	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** Maximum annual dose to MEI : 0.057 – 0.26 mrem/yr	**Noninvolved Workers:** No impacts
Maximum annual cancer risk to MEI: $2 \times 10^{-8} – 4 \times 10^{-8}$ per year		Maximum annual cancer risk to MEI: $2 \times 10^{-8} – 1 \times 10^{-7}$ per year	
Total collective dose (3 sites): 0.12 person-rem		Total collective dose (3 sites): 0.47 person-rem	
Total number of LCFs (3 sites): 5×10^{-5} LCF		Total number of LCFs (3 sites): 0.0002 LCF	
General Public: Maximum annual dose to MEI: 0.02 – 0.16 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.026 – 0.49 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.022 – 0.46 mrem/yr	**General Public:** Maximum annual dose to MEI: 0.021 – 1.3 mrem/yr
Maximum annual cancer risk to MEI: $1 \times 10^{-8} – 8 \times 10^{-8}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} – 2 \times 10^{-7}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} – 2 \times 10^{-7}$ per year	Maximum annual cancer risk to MEI: $1 \times 10^{-8} – 7 \times 10^{-7}$ per year
Total collective dose to population within 50 miles (3 sites): 0.38 person-rem	Total collective dose to population within 50 miles (3 sites): not determined	Total collective dose to population within 50 miles (3 sites): 1.07 person-rem	Total collective dose to population within 50 miles (3 sites): not determined
Total number of LCFs in population within 50 miles (3 sites): 2×10^{-4} LCF	Total number of LCFs in population within 50 miles (3 sites): not determined	Total number of LCFs in population within 50 miles (3 sites): 0.0005 LCF	Total number of LCFs in population within 50 miles (3 sites): not determined

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Normal Operations: Chemical			
Noninvolved Workers: No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts	**Noninvolved Workers:** No impacts
General Public: No impacts	**General Public:** No impacts	**General Public:** No impacts	**General Public:** No impacts
Human Health – Accidents: Radiological			
Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents	Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents
Noninvolved Workers: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 8×10^{-6} per year Collective dose: 16 person-rem Number of LCFs: 6×10^{-3}		**Noninvolved Workers:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 8×10^{-6} per year Collective dose: 16 person-rem Number of LCFs: 6×10^{-3}	
General Public: Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 1×10^{-5} per year Collective dose to population within 50 miles: 63 person-rem Number of LCFs in population within 50 miles: 3×10^{-2}		**General Public:** Bounding accident consequences (per occurrence): Dose to MEI: 0.02 rem Risk of LCF to MEI: 1×10^{-5} per year Collective dose to population within 50 miles: 63 person-rem Number of LCFs in population within 50 miles: 3×10^{-2}	

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Human Health – Accidents: Chemical			
Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents	Bounding accident: vehicle-induced fire, 3 full 48G cylinders;[b] bounding accident frequency: 1 in 10,000 years to 1 in 1 million years	No accidents
Noninvolved Workers: Bounding accident consequences (per occurrence):		**Noninvolved Workers:** Bounding accident consequences (per occurrence):	
Number of persons with potential for adverse effects: 1,000 persons		Number of persons with potential for adverse effects: 1,000 persons	
Number of persons with potential for irreversible adverse effects: 300 persons		Number of persons with potential for irreversible adverse effects: 300 persons	
General Public: Bounding accident consequences (per occurrence):		**General Public:** Bounding accident consequences (per occurrence):	
Number of persons with potential for adverse effects: 1,900 persons		Number of persons with potential for adverse effects: 1,900 persons	
Number of persons with potential for irreversible adverse effects: 1 person		Number of persons with potential for irreversible adverse effects: 1 person	
Human Health — Accidents: Physical Hazards			
Construction and Operations: **All Workers:** Less than 1 (0.11) fatality, approximately 143 injuries	No activities in the long term	**Construction and Operations:** **All Workers:** Less than 1 (0.07) fatality, approximately 90 injuries	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Air Quality			
Construction: 24-hour PM_{10} potentially as large as 82% of standard and 96% of standard at the Paducah and K-25 sites, respectively. Concentrations of other pollutants all below 3% of respective standards. No construction at the Portsmouth site. **Operations:** 24-hour HF impact potentially as large as 23% of standard at the K-25 site. Criteria pollutant impacts all below 0.3% of respective standards.	No activities in the long term	**Construction:** 24-hour PM_{10} potentially as large as 82% of standard and 96% of standard at the Paducah and K-25 sites, respectively. Concentrations of other pollutants all below 3% of respective standards. No construction at the Portsmouth site. **Operations:** 24-hour HF impact potentially as large as 92% of standard at the K-25 site. Criteria pollutant impacts all below 0.1% of respective standards.	No activities in the long term
Water			
Construction: Negligible impacts **Operations:** Negligible impacts to surface water and groundwater	Negligible impacts to surface water and groundwater in the long term	**Construction:** No impacts **Operations:** Negligible impacts to surface water; negligible to minor impacts to groundwater	Negligible impacts to surface water and groundwater in the long term
Soil			
Construction: Minor, but temporary, impacts **Operations:** Negligible impacts	No activities in the long term	**Construction:** No impacts **Operations:** Negligible impacts	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
Socioeconomics			
Construction and Operations: Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public housing	No activities in the long term	**Construction and Operations:** Negligible to low impacts to ROI employment and population growth rates, vacant housing, and public housing	No activities in the long term
Ecology			
Construction: Negligible impacts **Operations:** Negligible impacts to vegetation and wildlife	Negligible impacts to vegetation and wildlife in the long term	**Construction:** Negligible impacts **Operations:** Negligible impacts to vegetation and wildlife	Negligible to low impacts to vegetation and wildlife in the long term
Waste Management			
Negligible impacts for the Portsmouth and K-25 sites; moderate impacts for the Paducah site waste management operations; negligible impacts to regional or national waste management operations for all three sites	No activities in the long term	Negligible impacts for the Portsmouth and K-25 sites; moderate impacts for the Paducah site waste management operations; negligible impacts to regional or national waste management operations for all three sites	No activities in the long term
Resource Requirements			
No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No activities in the long term	No impacts from resource requirements (such as electricity or materials) on the local or national scale are expected	No activities in the long term
Land Use			
Negligible impacts	No activities in the long term	Negligible impacts	No activities in the long term

TABLE D.1 (Cont.)

No Action Alternative		Action Alternatives	
Impacts during Storage (1999-2039)	Long-Term Impacts	Impacts during Storage (1999-2028)	Long-Term Impacts
	Cultural Resources		
No impacts at the Paducah and Portsmouth sites. Impacts cannot be determined at K-25 for construction	No activities in the long term	No impacts at the Paducah and Portsmouth sites. Impacts cannot be determined at K-25 for construction	No activities in the long term
	Environmental Justice		
No disproportionate impacts	No activities in the long term	No disproportionate impacts	No activities in the long term

[a] Under the no action alternative, continued storage of the entire cylinder inventory would take place at the three sites; under the action alternatives, the number of cylinders stored at the three sites would decrease by 5% annually from 2009 through 2028.

Under all alternatives, potential long-term impacts were evaluated for uranium contamination of soil and groundwater from cylinder breaches through 2028 or 2039.

[b] The bounding radiological accident was defined as the accident that would result in the highest dose and risk to the general public MEI; the bounding chemical accident was defined as the accident that would result in the highest population risk (number of people affected).

Notation: HF = hydrogen fluoride; LCF = latent cancer fatality; MEI = maximally exposed individual; PM_{10} = particulate matter with a mean diameter of 10 µm or less; ROI = region of influence.

D.2 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE FOR THE NO ACTION ALTERNATIVE

The potential environmental impacts from continued cylinder storage for the no action alternative were evaluated on the basis of activities that were assumed to be required to ensure safe storage of the cylinders (Parks 1997). These activities include routine and ultrasonic inspections of cylinders, valve maintenance, cylinder painting, storage yard reconstruction, and cylinder relocations. Although these activities would minimize the occurrence of cylinder breaches and would aid in the early identification of breached cylinders, the impacts associated with cylinder breaches that might occur during continued storage were assessed. The assessment methodologies are described in Appendix C.

Assumptions for continued storage were generally selected in a manner intended to produce conservative estimates of impact, that is, the assumptions result in an overestimate of the expected impact. Therefore, although actual activities occurring at the three storage sites during the time period considered might vary, the estimated impacts of continued storage activities assessed in this PEIS are likely to encompass and bound the impacts that could occur at these sites. The following general assumptions apply to continued cylinder storage for the no action alternative:

- The current inventories of cylinders at the three sites would be maintained at the sites through the year 2039.

- The number of breaches assumed to occur under the no action alternative accounts for continued external corrosion prior to the completion of painting of the cylinder inventory. After painting, external corrosion was assumed to cease. Estimated numbers of breaches initiated by mechanical damage caused during cylinder handling are also included. Although current maintenance procedures would most likely lead to immediate identification and repair of any cylinder breaches, some releases of uranium and HF from breached cylinders were assumed for assessment purposes. Impacts were assessed for workers handling the breached cylinders, as well as for noninvolved workers and members of the general public exposed to materials released from breached cylinders.

- To assess potential long-term impacts to groundwater and human health and safety from breached cylinders, potential future groundwater contamination was assessed by assuming that released uranium would be transported from the cylinder storage yards in surface runoff and then migrate through the soil and into groundwater. It was further assumed that public access would be possible for groundwater at the location of the nearest discharge point (i.e., the nearest surface water body in the direction of groundwater flow).

- To address uncertainty in corrosion and cylinder breach assumptions, an assessment was also conducted assuming that external corrosion was not halted by improved maintenance conditions (see Section D.3 for a discussion of potential impacts).

D.2.1 Human Health — Normal Operations

D.2.1.1 Radiological Impacts

Radiological impacts from normal operations of the cylinder storage yards were assessed for the involved workers, noninvolved workers, and off-site general public. Radiation exposures of involved workers would result primarily from external radiation from inspecting and handling the cylinders. Exposures of noninvolved workers would result from airborne releases of uranyl fluoride (UO_2F_2) from breached cylinders. In addition to exposures from airborne releases of UO_2F_2, the analysis also considered potential exposures of the off-site public to waterborne releases of UO_2F_2. Such releases would be possible if UO_2F_2 was deposited on the ground surface and washed off by rain to a surface water body or infiltrated with rain to the deeper soil, thereby reaching the groundwater underlying the storage yards. Detailed discussions of the methodologies used in radiological impact analyses are provided in Appendix C and Cheng et al. (1997).

The estimated radiation doses and latent cancer risks for each of the three storage sites are provided in Tables D.2 and D.3, respectively. During the storage periods, average radiation exposures of involved workers would be less than 750 mrem/yr; exposures of noninvolved workers and members of the general public would be less than 1 mrem/yr. The long-term effects of radiation exposure on the general public resulting from groundwater contamination would be less than 2 mrem/yr. Potential long-term radiological impacts (based on groundwater contamination) are provided in Table D.4.

D.2.1.1.1 Paducah Site

The average annual collective worker dose for continued storage activities at the Paducah site would be about 22 person-rem/yr for about 30 workers for the period from 1999 through 2039. The number of workers required for this period was estimated on the basis of the anticipated activities (Parks 1997) and the assumption that the workers would work 5 hours per day in the storage yard. The average individual worker dose would vary from year to year and was estimated to average 740 mrem/yr, which is considerably below the regulatory limit of 5,000 mrem/yr (*10 Code of Federal Regulations* [CFR] Part 835) and also below the DOE administrative control limit of 2,000 mrem/yr (DOE 1992). Compared with the historical data for worker exposure of 16 to 56 mrem/yr (Hodges 1996), the estimated exposures are greater because of the conservative

TABLE D.2 Radiological Doses from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Annual Dose to Receptor					
	Involved Workers[a]		Noninvolved Workers[b]		General Public	
Site	Average Individual Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[c] (mrem/yr)	Collective Dose[d] (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Paducah	740	22	0.11	0.0023	0.013 (< 0.017)	0.0053
Portsmouth	600	9.2	0.043	0.00031	0.012 (< 0.0077)	0.0013
K-25	410	4.9	0.048	0.00021	0.11 (< 0.051)	0.0026

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. The reported values are averages over the time period 1999-2039. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest dose. The reported values are the maximums over the time period considered.

[d] The reported collective doses are averages over the time periods considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest dose. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective dose was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.3 Latent Cancer Risks from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Annual Risk of Latent Cancer Fatality to Receptor					
	Involved Worker[a]		Noninvolved Worker[b]		General Public	
Site	Average Individual Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[c] (risk/yr)	Collective Risk[d] (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Paducah	3×10^{-4}	9×10^{-3}	4×10^{-8}	9×10^{-7}	6×10^{-9} ($< 2 \times 10^{-9}$)	3×10^{-6}
Portsmouth	2×10^{-4}	4×10^{-3}	2×10^{-8}	1×10^{-7}	6×10^{-9} ($< 8 \times 10^{-10}$)	6×10^{-7}
K-25	2×10^{-4}	2×10^{-3}	2×10^{-8}	8×10^{-8}	5×10^{-8} ($< 5 \times 10^{-9}$)	1×10^{-6}

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population. The reported values are averages over the time period 1999-2039.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest risk. The reported values are the maximums over the time period considered.

[d] The reported collective risks are averages over the time period considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest risk. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective risk was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.4 Long-Term Radiological Impacts to Human Health from Continued Cylinder Storage under the No Action Alternative[a,b]

	Impact to MEI of General Public	
Storage Location	Radiation Dose[c] (mrem/yr)	Latent Cancer Risk[c] (risk/yr)
Paducah site	0.051 – 0.41	$3 \times 10^{-8} – 2 \times 10^{-7}$
Portsmouth site	0.026 – 0.33	$1 \times 10^{-8} – 2 \times 10^{-7}$
K-25 site	0.051 - 0.49	$3 \times 10^{-8} – 2 \times 10^{-7}$

[a] The long-term impacts correspond to the time after the year 2039.

[b] Long-term impacts would be caused by the potential use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. Contamination of groundwater would result from releases from hypothetically breached cylinders and the resulting infiltration of UO_2F_2 to the deeper soils, eventually reaching the groundwater (UO_2F_2 is the product of UF_6 reacting with moisture in air).

[c] Radiation doses and latent cancer risks are expressed as ranges, which would result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2039, assuming no mitigation action was taken.

assumptions made regarding future inspection and maintenance activities (Parks 1997) and the conservatism applied in the analytical methods (see Appendix C, Section C.4.1).

Radiation doses to noninvolved workers who worked on-site but not within the cylinder storage yards would be less than 0.11 mrem/yr, primarily from inhalation of UO_2F_2 released from breached cylinders. Radiation exposures of members of the off-site general public would result from both airborne and waterborne releases of UO_2F_2. The radiation dose to the maximally exposed individual (MEI) would be less than 0.03 mrem/yr (0.013 mrem/yr from exposure to airborne releases and 0.017 mrem/yr from using contaminated groundwater). The radiation dose from drinking contaminated surface water would be less than 2×10^{-7} mrem/yr. The dose of 0.03 mrem/yr is considerably below the regulatory limit of 10 mrem/yr (40 CFR Part 61) from airborne emissions and 100 mrem/yr (DOE Order 5400.5) from all exposure pathways. The exposure to the off-site public from continued storage activities would be very small compared with the existing exposures (about 3.03 mrem/yr) (LMES 1996a) from operations of the entire Paducah site.

Potential exposures to members of the off-site public after the year 2039 were also assessed for the use of contaminated groundwater resulting from breaches occurring prior to 2039. Depending on the soil properties that determine the time it takes the uranium to reach the groundwater, the maximum individual dose could range from 0.051 to 0.41 mrem/yr, which is considerably lower than the regulatory limit of 100 mrem/yr.

D.2.1.1.2 Portsmouth Site

In general, the estimated radiation doses from continued storage activities at the Portsmouth site would be less than those for the Paducah site because a smaller number of cylinders would be managed at Portsmouth. The average annual collective worker dose would be 9.2 person-rem/yr for about 16 workers for the period from 1999 through 2039. The average individual worker dose would be about 600 mrem/yr for this operational period, which is below the regulatory limit of 5,000 mrem/yr and the DOE administrative control limit of 2,000 mrem/yr. The estimated average worker dose is greater than the historical data of 55 to 196 mrem/yr (Hodges 1996) because of the more vigorous inspection and maintenance activities planned to be implemented. The radiation dose to noninvolved workers from airborne release of UO_2F_2 would be less than 0.043 mrem/yr for all periods.

The radiation dose to the maximally exposed member of the public would be less than 0.02 mrem/yr (0.012 mrem/yr from airborne releases plus 0.0077 mrem/yr from using contaminated groundwater), considerably below the regulatory limit of 10 mrem/yr from airborne emissions and 100 mrem/yr from all exposure pathways. The radiation dose from drinking contaminated surface water would be 2.1×10^{-5} mrem/yr. Compared with the existing exposure from operations for the entire Portsmouth site (0.066 mrem/yr; LMES 1996b), the dose to the MEI from continued storage activities would be smaller. The long-term radiological impacts to the general public from using contaminated groundwater would range from 0.026 to 0.33 mrem/yr — depending on the soil properties, which would determine the time it took for the uranium to reach the groundwater.

D.2.1.1.3 K-25 Site

The estimated radiation doses to involved workers from continued storage activities at the K-25 site would be less than those for the Paducah and Portsmouth sites because the smallest number of cylinders would be managed at K-25. The average annual collective worker dose would be about 4.9 person-rem/yr for approximately 13 workers for the period from 1999 through 2039. The average individual dose would be about 410 mrem/yr for this period, considerably below the regulatory limit of 5,000 mrem/yr and the DOE administrative control limit of 2,000 mrem/yr. Exposure of involved workers would be greater than the historical data of 32 to 92 mrem/yr (Hodges 1996) because of more worker activities planned to be implemented. Radiation exposure of noninvolved workers at the K-25 site would be less than 0.048 mrem/yr from airborne release of UO_2F_2.

The radiation dose to the MEI of the off-site public resulting from breached cylinders at the K-25 site would be greater than the doses at the Paducah and Portsmouth sites because of the shorter distance assumed between the emission point and the site boundary. As a result, the estimated radiation dose to the MEI of the general public would also be greater than the dose to noninvolved workers. Potential exposure of the general public MEI would be less than 0.16 mrem/yr (0.11 mrem/yr from exposure to airborne releases and 0.051 mrem/yr from using contaminated groundwater). The radiation dose from drinking contaminated surface water would be less than 0.000011 mrem/yr. The radiation dose of 0.16 mrem/yr would be less than the existing exposure of approximately 5 mrem/yr from operation of the entire Oak Ridge Reservation (LMES 1995). The long-term radiological impacts to the general public from using contaminated groundwater would range from 0.051 to 0.49 mrem/yr, which is very low compared with the dose limit of 100 mrem/yr from all exposure pathways.

D.2.1.2 Chemical Impacts

Chemical impacts during continued cylinder storage could result primarily from exposure to UO_2F_2 (the product formed when UF_6 is exposed to moist air) and HF released from hypothetical cylinder breaches. Risks from normal operations were quantified on the basis of calculated hazard indexes. Detailed discussions of the exposure assumptions, health effects assumptions, reference doses used for uranium compounds and HF, and calculational methods used in the chemical impact analysis are provided in Appendix C and Cheng et al. (1997).

Hazardous chemical impacts to the MEI at the three current storage yards were calculated for both noninvolved workers and members of the general public; the results are summarized in Table D.5. Chemical exposures of noninvolved workers and the off-site general public could result from airborne emissions of UO_2F_2 and HF that could be dispersed from hypothetical cylinder breaches into the atmosphere and to the ground surface. The exposure pathways assessed included inhalation of UO_2F_2 and HF and ingestion of UO_2F_2 in soil. In all cases, the MEI hazard index would be considerably below 1, indicating no potential adverse health effects.

D.2.2 Human Health — Accident Conditions

A range of accidents covering the spectrum of high-frequency/low-consequence accidents to low-frequency/high-consequence accidents was presented in the safety analysis reports (SARs) for the three storage sites (LMES 1997a–c). The potential accidents discussed in the SARs included natural phenomena events such as earthquakes, tornadoes, and floods, and spills from corroded cylinders under various weather conditions. The accidents selected for PEIS analyses were those accident scenarios in the SARs that resulted in the greatest potential consequences at each of the three storage sites for each of the four frequency categories (likely, unlikely, extremely unlikely, and incredible); these accidents are listed in Table D.6. The accidents selected for the PEIS analyses and

TABLE D.5 Chemical Impacts to Human Health from Continued Cylinder Storage under Normal Operations for the No Action Alternative

	Impacts to Receptor			
	Noninvolved Workers[a]		General Public[b]	
Site/Time Period	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)
Paducah site				
1999-2039	1.0×10^{-3}	–	2.6×10^{-3} ($\leq 2.1 \times 10^{-3}$)	–
Long-term impacts[e]	NA[f]	–	0.01 – 0.05	–
Portsmouth site				
1999-2039	4.4×10^{-5}	–	2.6×10^{-3} ($\leq 9.7 \times 10^{-4}$)	–
Long-term impacts[e]	NA	–	0.003 – 0.04	–
K-25 site				
1999-2039	4.8×10^{-4}	–	2.3×10^{-2} ($\leq 6.4 \times 10^{-3}$)	–
Long-term impacts[e]	NA	–	0.01 – 0.06	–

[a] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. The MEI for the noninvolved worker was assumed to be at the on-site (outside storage yards) location that would yield the largest exposure. Exposures would result from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders; the exposure pathways considered included inhalation and incidental ingestion of soil.

[b] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposure. Results reported are the maximum values over the time period considered and would result from exposure via inhalation; ingestion of soil (resulting from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders); and drinking surface water (consequence of the discharge of contaminated runoff water to a surface water body). Potential impacts during the storage period 1999-2039 (values within parentheses) were also evaluated from the use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] Calculation of population risk is not applicable when the corresponding hazard index for the MEI is less than 1.

[e] Long-term impacts would result from using contaminated groundwater. Ranges result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2039, assuming no mitigative measures were taken.

[f] NA = not applicable; workers were assumed not to ingest groundwater.

TABLE D.6 Accidents Considered for the Continued Storage Option

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Paducah Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Vehicle-induced fire, 3 full 48Y cylinders	Three full 48Y UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 18,000 2,770 8,010	0 to 24 24 24 to 30 30 to 236	Ground
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Small plane crash, 2 full 48Y cylinders	A small plane crash affects two full 48Y UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 6,020 920 2,670	0 to 24 24 24 to 30 30 to 236	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	3,210 2,730	0 to 30 30 to 236	Ground

TABLE D.6 (Cont.)

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
Portsmouth Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Corroded cylinder spill, wet conditions – water pool	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area into a 0.25-in. deep water pool.	HF	150	60 (continuous)	Ground
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Vehicle-induced fire, 3 full 48Y cylinders	Three full 48Y UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 18,000 2,770 8,010	0 to 24 24 24 to 30 30 to 236	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground
Small plane crash, 2 full 48Y cylinders	A small plane crash affects two full 48Y UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 6,020 920 2,670	0 to 24 24 24 to 30 30 to 236	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	3,210 2,730	0 to 30 30 to 236	Ground

TABLE D.6 (Cont.)

Site/Accident Scenario	Accident Description	Chemical Form	Amount (lb)	Duration (min)	Release Level[a]
K-25 Site					
Likely Accidents (frequency: 1 or more times in 100 years)					
Corroded cylinder spill, dry conditions	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the dry ground.	UF_6	24	60 (continuous)	Ground
Unlikely Accidents (frequency: 1 in 100 years to 1 in 10,000 years)					
Corroded cylinder spill, wet conditions – rain	A 1-ft hole results during handling, with solid UF_6 forming a 4-ft^2 area on the wet ground.	HF	96	60 (continuous)	Ground
Extremely Unlikely Accidents (frequency: 1 in 10,000 years to 1 in 1 million years)					
Vehicle-induced fire, 3 full 48G cylinders	Three full 48G UF_6 cylinders hydraulically rupture during a fire resulting from the ignition of fuel and/or hydraulic fluid from the transport vehicle, etc.	UF_6	0 11,500 8,930 3,580	0 to 12 12 12 to 30 30 to 121	Ground
Incredible Accidents (frequency: less than 1 in 1 million years)					
Small plane crash, 2 full 48G cylinders	A small plane crash affects two full 48G UF_6 cylinders. One cylinder hydraulically ruptures during a fire resulting from the ignition of aviation fuel.	UF_6	0 3,840 2,980 1,190	0 to 12 12 12 to 30 30 to 121	Ground
	The second cylinder is initially breached due to impact with aircraft debris, followed by sublimation due to fire.	UF_6	4,240 1,190	0 to 30 30 to 121	Ground

[a] Ground-level releases were assumed to occur outdoors on the concrete pads in the cylinder storage yards. To prevent contaminant migration, cleanup of residuals was assumed to begin immediately after the release was stopped.

listed in Table D.6 do not include natural phenomena events, which were found in the SARs to have less serious consequences than other types of accident scenarios (e.g., a vehicle-induced fire affecting three UF_6 cylinders). In those instances where it was not absolutely clear from the SAR which accident would be the bounding accident in a frequency category at a site, several accidents were included in the PEIS analyses, as indicated in Table D.6. The resulting radiological doses and adverse health impacts from chemical exposures for all the accidents listed in Table D.6 are presented in Policastro et al. (1997). In the following sections, the results for only the bounding accident in each frequency category at each site are presented. Detailed descriptions of the methodology and assumptions used in these calculations are provided in Appendix C and Policastro et al. (1997).

D.2.2.1 Radiological Impacts

Table D.7 lists the radiological doses to various receptors for the accidents that give the highest dose from each frequency category. The LCF risks for these accidents are given in Table D.8. The doses and the risks are presented for two different meteorological conditions (D and F stability classes) at the three current storage sites (see Appendix C). The doses and risks presented here were obtained by assuming that the accidents would occur. The probability of occurrence for each accident is indicated by the frequency category to which it belongs. For example, accidents in the extremely unlikely (EU) category have a probability of occurrence between 1 in 10,000 and 1 in 1 million in any 1 year. The following conclusions may be drawn from the radiological health impact results:

- No cancer fatalities would be predicted from any of the accidents.

- The maximum radiological dose to worker and general public MEIs (assuming that an accident occurred) would be 0.077 rem. This dose is less than the 25-rem dose recommended for assessing the adequacy of protection of public health and safety from potential accidents by the U.S. Nuclear Regulatory Commission (NRC 1994).

- The overall radiological risk to worker and general public MEI receptors (estimated by multiplying the risk per occurrence [Table D.8] by the annual probability of occurrence by the number of years of operations) would be less than 1 for all of the continued storage accidents.

D.2.2.2 Chemical Impacts

The accidents discussed in this section are listed in Table D.6. The results of the accident consequence modeling in terms of chemical impacts are presented in Tables D.9 and D.10. The results are presented as (1) number of persons with the potential for adverse effects and (2) number of persons with the potential for irreversible adverse effects. The tables present the results for the accident within each frequency category that would affect the largest number of people (total of workers and off-site population) (Policastro et al. 1997). The impacts presented are based on the assumption that the accidents would occur. The accidents listed in Tables D.9 and D.10 are not identical because an accident with the largest impacts for the adverse effects endpoint might not lead to the largest impacts for the irreversible adverse effects endpoint. Detailed descriptions of the

TABLE D.7 Estimated Radiological Doses per Accident Occurrence for Continued Cylinder Storage under the No Action Alternative

		Maximum Dose[c]				Minimum Dose[c]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[a]	Frequency Category[b]	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)	MEI (rem)	Population (person-rem)
Paducah									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	1.4	2.3×10^{-3}	2.6×10^{-1}	3.3×10^{-3}	6.3×10^{-2}	9.8×10^{-5}	3.0×10^{-2}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.5×10^{1}	1.5×10^{-2}	2.8×10^{1}	3.7×10^{-3}	1.3	1.9×10^{-3}	1.1
Portsmouth									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	2.2	2.2×10^{-3}	2.1×10^{-1}	3.3×10^{-3}	9.5×10^{-2}	9.3×10^{-5}	2.8×10^{-2}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.6×10^{1}	1.3×10^{-2}	3.2×10^{1}	3.7×10^{-3}	2.0	1.9×10^{-3}	1.6
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	5.3	4.3×10^{-3}	5.5×10^{-1}	8.7×10^{-4}	6.9×10^{-1}	6.2×10^{-4}	7.6×10^{-2}
K-25									
Corroded cylinder spill, dry conditions	L	7.7×10^{-2}	1.3	2.7×10^{-3}	4.3×10^{-1}	3.3×10^{-3}	6.0×10^{-2}	1.1×10^{-4}	5.9×10^{-2}
Vehicle-induced fire, 3 full 48G cylinders	EU	2.0×10^{-2}	1.6×10^{1}	1.3×10^{-2}	6.3×10^{1}	3.7×10^{-3}	2.4	1.9×10^{-3}	2.2
Small plane crash, 2 full 48G cylinders	I	6.6×10^{-3}	5.4	4.3×10^{-3}	7.4×10^{-1}	8.7×10^{-4}	6.9×10^{-1}	7.1×10^{-4}	1.0×10^{-1}

[a] The bounding accident chosen to represent each frequency category is the one that would result in the highest dose to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[b] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[c] Maximum and minimum doses reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum doses would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum doses would occur under D stability with 4 m/s wind speed. An exception is the vehicle-induced fire involving 3 full 48G cylinders, which would result in a higher population dose for the general public under D stability with 4 m/s wind speed.

TABLE D.8 Estimated Radiological Health Risks per Accident Occurrence for Continued Cylinder Storage under the No Action Alternative[a]

		Maximum Risk[d] (LCFs)				Minimum Risk[d] (LCFs)			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI	Population	MEI	Population	MEI	Population	MEI	Population
Paducah									
Corroded cylinder, dry conditions	L	3×10^{-5}	6×10^{-4}	1×10^{-6}	1×10^{-4}	1×10^{-6}	3×10^{-5}	5×10^{-8}	1×10^{-5}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	7×10^{-6}	1×10^{-2}	1×10^{-6}	5×10^{-4}	1×10^{-6}	5×10^{-4}
Portsmouth									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	9×10^{-4}	1×10^{-6}	1×10^{-4}	1×10^{-6}	4×10^{-5}	5×10^{-8}	1×10^{-5}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	6×10^{-6}	2×10^{-2}	1×10^{-6}	8×10^{-4}	1×10^{-6}	8×10^{-4}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	2×10^{-3}	2×10^{-6}	3×10^{-4}	3×10^{-7}	3×10^{-4}	3×10^{-7}	4×10^{-5}
K-25									
Corroded cylinder spill, dry conditions	L	3×10^{-5}	5×10^{-4}	1×10^{-6}	2×10^{-4}	1×10^{-6}	2×10^{-5}	6×10^{-8}	3×10^{-5}
Vehicle-induced fire, 3 full 48G cylinders	EU	8×10^{-6}	6×10^{-3}	7×10^{-6}	3×10^{-2}	1×10^{-6}	9×10^{-4}	1×10^{-6}	1×10^{-3}
Small plane crash, 2 full 48G cylinders	I	3×10^{-6}	2×10^{-3}	2×10^{-6}	4×10^{-4}	3×10^{-7}	3×10^{-4}	4×10^{-7}	5×10^{-5}

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (LCF) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one that would result in the highest risk to the general public MEI. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category. Absence of an accident in a certain frequency category indicates that the accident would not result in a release of radioactive material.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations ($> 10^{-2}$/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations ($10^{-4} – 10^{-6}$/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations ($< 10^{-6}$/yr).

[d] Maximum and minimum risks reflect differences in assumed meteorological conditions at the time of the accident. In general, maximum risks would occur under meteorological conditions of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed. An exception is the vehicle-induced fire involving 3 full 48G cylinders, which would result in a higher population dose for the general public under D stability with 4 m/s wind speed.

TABLE D.9 Number of Persons with Potential for Adverse Effects from Accidents under Continued Cylinder Storage for the No Action Alternative[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Paducah									
Corroded cylinder spill, dry conditions	L	Yes	10	No	0	Yes	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	690	Yes	14	Yes	7	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	910	Yes	1,900	Yes	4	Yes	3
Portsmouth									
Corroded cylinder spill, dry conditions	L	Yes	48	Yes[f]	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	850	Yes	12	Yes	2	Yes[f]	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	1,000	Yes	650	Yes	160	Yes	4
Small plane crash, 2 full 48Y cylinders	I	Yes	760	Yes	6	No	0	No	0
K-25									
Corroded cylinder spill, dry conditions	L	Yes	69	No	0	Yes[f]	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	700	Yes	18	Yes	47	No	0
Vehicle-induced fire, 3 full 48G cylinders	EU	Yes	770	Yes	550	No	0	Yes	12
Small plane crash, 2 full 48G cylinders	I	Yes	420	Yes	34	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under the meteorological condition of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either “Yes” or “No” for potential adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the actual worker and general public population distributions were used, which did not show receptors at the MEI locations.

TABLE D.10 Number of Persons with Potential for Irreversible Adverse Effects from Accidents under Continued Cylinder Storage for the No Action Alternative[a]

		Maximum Number of Persons[d]				Minimum Number of Persons[d]			
		Noninvolved Workers		General Public		Noninvolved Workers		General Public	
Site/Accident[b]	Frequency Category[c]	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population	MEI[e]	Population
Paducah									
Corroded cylinder spill, dry conditions	L	Yes	1	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	130	Yes[f]	0	Yes	1	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	300	Yes	1	Yes	1	No	0
Portsmouth									
Corroded cylinder spill, dry conditions[g]	L	Yes	0	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	90	Yes	1	Yes	0	No	0
Corroded cylinder spill, wet conditions – water pool	EU	Yes	110	Yes[f]	1	Yes	0	No	0
Small plane crash, 2 full 48Y cylinders[g]	I	No	0	No	0	No	0	No	0
K-25									
Corroded cylinder spill, dry conditions	L	Yes	3	No	0	No	0	No	0
Corroded cylinder spill, wet conditions – rain	U	Yes	140	Yes	0	Yes	2	No	0
Vehicle-induced fire, 3 full 48Y cylinders[g]	EU	No	0	No	0	No	0	No	0
Small plane crash, 2 full 48G cylinders[g]	I	No	0	No	0	No	0	No	0

[a] Values shown are the consequences if the accident did occur. The risk of an accident is the consequence (number of persons) times the estimated frequency times 20 years of operations. The estimated frequencies are as follows: likely (L), 0.1; unlikely (U), 0.001; extremely unlikely (EU), 0.00001; incredible (I), 0.000001.

[b] The bounding accident chosen to represent each frequency category is the one in which the largest number of people (workers plus off-site people) would be affected. Health impacts in that row represent that accident only and not the range of impacts among accidents in that category.

[c] Accident frequencies: likely (L), estimated to occur one or more times in 100 years of facility operations (> 10^{-2}/yr); unlikely (U), estimated to occur between once in 100 years and once in 10,000 years of facility operations (10^{-2} – 10^{-4}/yr); extremely unlikely (EU), estimated to occur between once in 10,000 years and once in 1 million years of facility operations (10^{-4} – 10^{-6}/yr); incredible (I), estimated to occur less than one time in 1 million years of facility operations (< 10^{-6}/yr).

[d] Maximum and minimum risks reflect different meteorological conditions at the time of the accident. In general, maximum risks would occur under the meteorological condition of F stability with 1 m/s wind speed, whereas minimum risks would occur under D stability with 4 m/s wind speed.

[e] At the MEI location, the determination is either “Yes” or “No” for potential irreversible adverse effects to an individual.

[f] MEI locations were evaluated at 100 m from ground-level releases for workers and at the location of highest off-site concentration for members of the general public; the population risks are 0 because the actual worker and general public population distributions were used, which did not show receptors at the MEI locations.

[g] These accidents would result in the largest plume sizes, although no people would be affected.

methodology and assumptions for assessing chemical impacts are provided in Appendix C). The following conclusions may be drawn from the chemical impact results:

- If the accidents identified in Tables D.9 and D.10 did occur, the number of persons in the off-site population with the potential for adverse effects would range from 0 to 1,900 (maximum corresponding to the vehicle-induced fire scenario at the Paducah site), and the number of off-site persons with potential for irreversible adverse effects would range from 0 to 7 (maximum corresponding to the corroded cylinder spill with pooling conditions scenario at the Portsmouth site).

- If the accidents identified in Tables D.9 and D.10 did occur, the number of noninvolved workers with the potential for adverse effects would range from 0 to 1,000 (maximum corresponding to the vehicle-induced fire scenario at the Portsmouth site), and the number of noninvolved workers with the potential for irreversible adverse effects would range from 0 to 300 (maximum corresponding to the corroded cylinder spill with pooling scenario at the Paducah site).

- Accidents resulting in a vehicle-induced fire involving three full 48G cylinders during very stable (nighttime) meteorological conditions would have a very low probability of occurrence but could affect a large number of people.

- The maximum risk was computed as the product of the consequence (number of people) times the frequency of occurrence (per year) times the number of years of operations (41 years, 1999-2039). The results indicate that the maximum risk values would be less than 1 for all accidents, except the following:

  - *Potential Adverse Effects:*

    Corroded cylinder spill, dry conditions (L, likely):
    Workers at the Paducah, Portsmouth, and K-25 sites

    Corroded cylinder spill, wet conditions – rain (U, unlikely):
    Workers at the Paducah, Portsmouth, and K-25 sites

  - *Potential Irreversible Adverse Effects:*

    Corroded cylinder spill, dry conditions (L likely):
    Workers at the Paducah and K-25 sites

    Corroded cylinder spill, wet conditions – rain (U, unlikely):
    Workers at the Paducah, Portsmouth, and K-25 sites

These risk values are conservative because the numbers of people affected were based on assuming (1) meteorological conditions that would result in the maximum reasonably foreseeable plume size (i.e., F stability and 1 m/s wind speed) and (2) wind in the direction that would lead to maximum numbers of individuals exposed for workers or for the general population.

To aid in the interpretation of accident analysis results, the number of fatalities potentially associated with the estimated potential irreversible adverse effects was estimated. All the bounding case accidents shown in Table D.10 would involve releases of UF_6 and potential exposure to HF and uranium compounds. These exposures would likely be high enough to result in death for 1% or less of the persons experiencing irreversible adverse effects (Policastro et al. 1997). This would mean that for workers experiencing a range of 0 to 300 irreversible adverse effects, approximately 0 to 3 deaths would be expected. Similarly, of the general public experiencing a range of 0 to 1 irreversible adverse effects, less than 1 death would be expected. These are the maximum potential consequences of the accidents, the upper ends of the ranges assume worst-case weather conditions and that the wind would be blowing in the direction where the highest number of people would be exposed.

D.2.2.3 Physical Hazards

The risk of on-the-job fatalities and injuries for workers (involved and noninvolved) conducting activities associated with continued storage was calculated using industry-specific statistics from the U.S. Bureau of Labor Statistics, as reported by the National Safety Council (1995). Annual fatality and injury rates for manufacturing activities were used for all activities except cylinder yard construction or reconstruction; rates specific to construction were available for these activities. Injury incidence rates used were for injuries involving lost workdays (not including the day of injury). No on-the-job fatalities and less than 100 injuries would be expected during the entire continued cylinder storage period.

The activities included as part of the continued storage strategy are routine cylinder inspections, ultrasonic inspections, valve monitoring and maintenance activities, cylinder relocations, cylinder yard construction or reconstruction, cylinder painting, and patching and content transfers for breached cylinders (Parks 1997). These activities were assumed to be continued at currently planned levels through the year 2039, except for yard construction and reconstruction, which were assumed to be completed by the year 2003. The annual labor requirements and the corresponding fatality and injury risks for these activities were estimated to be as follows: the total three-site fatality risk would be less than 1 (0.11), and the total three-site injury risk would be about 140 injuries (see Table D.11).

TABLE D.11 Estimated Impacts to Human Health from Physical Hazards under Continued Cylinder Storage for the No Action Alternative[a,b]

Impacts to All Workers (Involved and Noninvolved)[c]							
Fatality Incidence				Injury Incidence			
Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites	Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites
0.056	0.030	0.026	0.11	71	39	33	143

[a] Potential impacts are based on continued storage activities, which would include routine inspections, ultrasonic inspections, valve monitoring and maintenance, cylinder relocations, cylinder yard construction and reconstruction, cylinder painting, and patching and content transfers for breached cylinders for the time period 1999-2039.

[b] Risk estimates include reconstruction of L-, M-, N-, and P-yards at Paducah and construction of a new yard at K-25.

[c] Injury and fatality incidence rates used in the calculations were taken from National Safety Council (1995).

D.2.3 Air Quality

The analysis of air quality impacts for continued cylinder storage under the no action alternative was based on three emissions-producing activities: (1) construction of new storage yards; (2) relocation and painting of cylinders; and (3) estimated HF emissions resulting from hypothetical cylinder breaches. The air quality impacts of these three activities are addressed by site in Sections D.2.3.1 through D.2.3.3. Additional details on the assessment of air quality impacts is presented in Tschanz (1997a-b).

D.2.3.1 Paducah Site

The potential impacts of construction were modeled on the basis of assuming area sources located at the yards being reconstructed. The maximum impacts at the Paducah site would occur in 1999 when the L-yard is scheduled for reconstruction. The 1-hour and annual maximum concentrations of criteria pollutants — hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM_{10}) — that would occur during construction of that yard are listed in Table D.12. The annual PM_{10} concentration of 16.7 $\mu g/m^3$ is about 33% of the applicable 50 $\mu g/m^3$ standard. The 24-hour estimated maximum PM_{10} concentration of 131 $\mu g/m^3$ is 87% of the 150 $\mu g/m^3$ standard. With monitored 24-hour PM_{10} concentrations in the vicinity of the Paducah site in the range of 50 to 60 $\mu g/m^3$, the estimated maximum concentration from construction of the yard could raise the total above the standard. The construction fugitive dust

TABLE D.12 Maximum Concentrations of Criteria Pollutants at Site Boundaries during Yard Construction[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]
Paducah Site								
CO	220	0.0055	112	0.011	37.3	–	4.76	–
HC[c]	22.5	–	11.5	–	3.84	–	0.489	–
NO_x	85.0	–	43.4	–	14.5	–	1.85	0.02
SO_x	9.02	–	4.59	–	1.53	–	0.196	0.003
PM_{10}	768	–	391	–	131	0.87	16.7	0.33
K-25 Site								
CO	266	0.0067	122	0.012	41.1	–	7.66	–
HC[c]	27.3	–	12.5	–	4.22	–	0.787	–
NO_x	103	–	47.1	–	15.9	–	2.97	0.03
SO_x	10.9	–	5.00	–	1.69	–	0.315	0.004
PM_{10}	930	–	425	–	144	0.96	26.8	0.54

[a] Paducah values are based on reconstruction of the L-yard; K-25 values are based on construction of a new yard assumed to be located at the site of the current K-yard. No yard construction is planned for the Portsmouth site.

[b] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

[c] HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

emissions used here were based on a general emission factor that considers only the size of the disturbed area and might be an overestimate for the actual use of construction equipment on the site.

Detailed information about the planned construction would be required to more accurately assess the likely actual impacts. However, because the construction site would be adjacent to the facility boundary, it is likely that some measures would be required to reduce the generation of fugitive dust during reconstruction of the yard. Other estimated pollutant concentrations are much smaller fractions of their respective standards, in general being of the order of 1 to 2% of the standard.

Relocating and painting cylinders would involve powered units that produce internal combustion emissions. The paint to be used on the cylinders would be an additional source of volatile organic compound (VOC) emissions (HC is an indicator of VOC sources). Because the relocation and painting of cylinders would generally occur at several locations for each site, emissions from those activities were modeled as point sources at the centers of the sites. The maximum number of annual cylinder relocations that would be required at Paducah during the no action alternative would be 4,200; the maximum number of cylinders painted annually would be 3,000. Table D.13 gives the estimated maximum concentrations of criteria pollutants at the Paducah site boundaries due to relocations; Table D.14 gives the estimated maximum concentrations due to painting activities.

Assumptions regarding the number of hypothetical cylinder breaches were used to estimate maximum annual HF emissions (Tschanz 1997b); these estimates are listed in Table D.15. The estimated 0.01 $\mu g/m^3$ maximum HF concentration at the Paducah site boundary is considerably below the Kentucky primary annual standard for HF of 0.5 ppm (400 $\mu g/m^3$).

TABLE D.13 Maximum Concentrations of Criteria Pollutants at Site Boundaries due to Cylinder Relocations[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]	Concentration ($\mu g/m^3$)	Fraction of Standard[b]
Paducah Site								
CO	13.3	0.0033	1.66	0.00017	0.554	–	0.0244	–
HC[c]	1.07	–	0.134	–	0.0448	–	0.00197	–
NO_x	1.59	–	0.199	–	0.0665	–	0.00292	0.00003
SO_x	3.84	–	0.482	–	0.161	–	0.00706	0.00009
PM_{10}	0.337	–	0.0423	–	0.0141	0.0009	0.000620	0.00001
K-25 Site								
CO	5.36	0.00013	1.40	0.00014	0.469	–	0.0277	–
HC[c]	0.434	–	0.113	–	0.0379	–	0.00224	–
NO_x	0.643	–	0.168	–	0.0562	–	0.00332	0.00003
SO_x	1.55	–	0.405	–	0.136	–	0.00803	0.0001
PM_{10}	0.136	–	0.0356	–	0.0119	0.00008	0.000705	0.00001

a Cylinder relocations are planned for the Paducah and K-25 sites during the time frame considered (1999-2039).

b Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

c HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

TABLE D.14 Maximum Concentrations of Criteria Pollutants at Site Boundaries due to Cylinder Painting[a]

	Estimated Maximum Criteria Pollutants							
	1-Hour Average		8-Hour Average		24-Hour Average		Annual Average	
Pollutant	Concen-tration ($\mu g/m^3$)	Fraction of Standard[b]	Concen-tration ($\mu g/m^3$)	Fraction of Standard[b]	Concen-tration ($\mu g/m^3$)	Fraction of Standard[b]	Concen-tration ($\mu g/m^3$)	Fraction of Standard[b]
Paducah Site								
CO	9.48	0.00024	1.19	0.00012	0.396	–	0.0174	–
HC[c]	127	–	15.9	–	5.31	–	0.233	–
NO_x	1.13	–	0.142	–	0.0472	–	0.0021	0.000021
SO_x	2.75	–	0.344	–	0.115	–	0.0050	0.000064
PM_{10}	0.244	–	0.031	–	0.0102	0.000068	0.00045	0.000009
Portsmouth Site								
CO	3.72	0.000093	0.583	0.000058	0.205	–	0.018	–
HC[c]	49.9	–	7.84	–	2.76	–	0.236	–
NO_x	0.445	–	0.070	–	0.025	–	0.0021	0.000021
SO_x	1.08	–	0.170	–	0.060	–	0.0051	0.000065
PM_{10}	0.097	–	0.015	–	0.0053	0.000035	0.00046	0.000092
K-25 Site								
CO	2.75	0.000069	0.716	0.000072	0.240	–	0.014	–
HC[c]	36.8	–	9.59	–	3.22	–	0.190	–
NO_x	0.321	–	0.084	–	0.028	–	0.0017	0.000017
SO_x	0.803	–	0.209	–	0.070	–	0.0042	0.000054
PM_{10}	0.064	–	0.017	–	0.0056	0.000037	0.00033	0.0000066

[a] Maximum pollutant concentrations are based on the maximum number of cylinders painted annually under the no action alternative: 3,000 at Paducah; 1,350 at Portsmouth; and 1,200 at K-25.

[b] Ratio of the upper end of the concentration range divided by the respective air quality standard. A ratio of less than 1 indicates that the standard would not be exceeded.

[c] HC, although not a criteria pollutant, was used to evaluate potential impacts to the criteria pollutant ozone.

TABLE D.15 Estimated Number of Breached Cylinders, Maximum HF Emissions, and Average Maximum HF Concentrations at the Existing Storage Sites under the No Action Alternative

Site	Maximum Number of Breaches Starting in a Single Year	Maximum Total Number of Active Breaches in a Single Year	Maximum HF Concentration ($\mu g/m^3$)	
			24-Hour Average	Annual Average
Paducah	2	5	0.08	0.0093
Portsmouth	2	3	0.10	0.011
K-25	1	2	0.66	0.084

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Paducah site. McCracken County in the Paducah-Cairo Interstate Air Quality Control Region is currently in attainment for all criteria pollutant standards, including ozone. The pollutants most related to ozone formation that could result from the continued storage options at the Paducah site would be HC and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in McCracken County, as recorded in the Kentucky Division of Air Quality Control "Emissions Inventory" for 1995 (Hogan 1996). The estimated maximum annual HC and NO_x emissions of 7.11 and 1.47 tons/yr would be only 1.2 and 0.004%, respectively, of the 1995 McCracken County emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the county.

D.2.3.2 Portsmouth Site

Because no storage yard construction is planned at the Portsmouth site, the maximum pollutant impacts, other than for HC, estimated at the facility boundary are much smaller than those estimated for the other two sites. The maximum criteria pollutant concentrations are shown in Table D.14; criteria pollutant emissions for Portsmouth are associated only with painting activities. For all pollutants, including PM_{10}, the concentrations are less than 0.1% of the standards. As shown in Table D.15, the HF concentrations would likewise be small (Tschanz 1997b). The State of Ohio does not have an ambient air quality standard for HF.

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the Portsmouth site. Pike and Scioto Counties in the Wilmington-Chillicothe-Logan Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from continued cylinder storage at the Portsmouth site would be HC and NO_x. The potential effects on ozone of those emissions can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Pike and Scioto Counties, as recorded in the Ohio Environmental Protection Agency "Emissions Inventory" for 1990 (Juris 1996). The estimated HC and NO_x emissions of 3.01 and 0.05 tons/yr from continued storage actions would be only 0.18 and 0.002%, respectively, of the 1990 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region.

D.2.3.3 K-25 Site

The maximum estimated criteria pollutant concentrations at the K-25 boundary during yard construction are shown in Table D.12. These maximum concentrations would occur when the planned new storage yard would be completed. The maximum monitored 24-hour PM_{10} concentration at the Y-12 site is about 29 $\mu g/m^3$, which when added to the estimated maximum PM_{10} concentration at the K-25 site brings the total above the 150 $\mu g/m^3$ standard. The qualifications regarding the estimated PM_{10} concentrations and the likelihood for a need of mitigative measures discussed above for the Paducah site also apply to these K-25 results. As for Paducah, all other criteria pollutant concentrations at K-25 would be well below their respective standards, generally being between 1 to 3% of the standard. For years during which no construction activities are planned, the maximum pollutant concentrations should not exceed air quality standards (Tables D.13 and D.14).

The maximum annual and 24-hour average HF concentrations from hypothetical cylinder breaches at K-25 are estimated to be the highest of the three storage sites, as shown in Table D.15 (Tschanz 1997b). In large part, these high concentrations are a result of the distance to the nearest facility boundary from the modeled location, which for the majority of HF point source emissions is shorter at the K-25 site than at either of the other two facilities. The estimated maximum 24-hour HF concentrations would be 0.66 $\mu g/m^3$, which is 23% of the State of Tennessee standard of 2.9 $\mu g/m^3$. The highest monitored 7-day HF concentration at the Y-12 site in 1992 was 0.28 $\mu g/m^3$.

No quantitative estimate was made of the impacts on the criteria pollutant ozone. Ozone formation is a regional issue affected by emissions data for the entire area around the K-25 site. Anderson and Roane Counties in the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region are currently in attainment for all criteria pollutant standards, including ozone. The pollutant emissions most related to ozone formation that could result from the continued storage options at the K-25 site would be HC and NO_x. The potential effects on ozone of those pollutants can be put in perspective by comparing them with the total emissions of HC and NO_x for point sources in Anderson and Roane Counties, as recorded in the Tennessee Division of Air Pollution Control "Emissions Inventory" for 1995 (Conley 1996). The estimated HC and NO_x emissions of 3.03 and 1.24 tons/yr would be only 0.11 and 0.002%, respectively, of the 1995 two-county emissions totals of those pollutants from inventoried point sources. These small additional contributions to the totals would be unlikely to alter the ozone attainment status of the region. The HC and NO_x emissions would be even smaller during later continued storage periods.

D.2.4 Water and Soil

Potential water and soil impacts for continued storage of cylinders under the no action alternative were evaluated for surface water, groundwater, and soils at each of the three storage facilities. Impacts to water and soil quality were evaluated by comparisons with U.S. Environmental Protection Agency (EPA) guidelines.

Water use for construction under the no action alternative was estimated to be 2 million gal for the Paducah site and 0.81 million gal for the K-25 site (no construction would occur at the Portsmouth site). Operational water use was estimated as ranging from 0.12 to 0.16 million gal/yr at Paducah, 0.055 to 0.06 million gal/yr at Portsmouth, and 0.025 to 0.032 million gal/yr at K-25.

D.2.4.1 Surface Water

The estimated number of cylinder breaches assumed to occur under the no action alternative is given in Appendix B; these estimates were used to calculate potential impacts to surface water quality. Each breached cylinder was assumed to release a maximum of 4 lb (1.8 kg) of uranium over a period of 4 years; additional details on the methodology used to evaluate the impacts are given in Appendix C and Tomasko (1997b).

The estimated maximum uranium concentrations in runoff water leaving the yards would be about 20, 19, and 52 µg/L (5, 5, and 13 pCi/L) for Paducah, Portsmouth, and K-25, respectively. These concentrations would occur in about 2002. The contaminated runoff was then assumed to flow without loss to the nearest surface water, where it would mix and be diluted. For average flow conditions, the dilution would be large enough that the maximum concentrations would be less than 0.7 µg/L (0.2 pCi/L) for all three sites (Table D.16). This concentration is less than the EPA proposed drinking water maximum contaminant level (MCL) for uranium of 20 µg/L, used here for comparison. The contaminated water would then mix with water in the Ohio River, Scioto River, or Clinch River, resulting in even greater dilution. Because of this mixing, impacts to the major rivers would not be measurable.

D.2.4.2 Groundwater

Groundwater impacts were assessed by assuming that water contaminated due to releases from hypothetical cylinder breaches would leave the yards as runoff and flow to the boundary of the nearest surface water (but not discharge to it), thereby creating a contaminated source on the ground surface. On the basis of the assumption that cylinder painting would control corrosion, the only impacts to groundwater would be to water quality; no impacts would occur to recharge, depth to water, or direction of flow (see Section D.3 for discussion of potential impacts based on assuming a greater number of breaches). Conservative estimates of the concentration of uranium in

TABLE D.16 Maximum Uranium Concentrations in Surface Waters for Continued Cylinder Storage under the No Action Alternative

Site	Receiving Water	Dilution Factor	Maximum Concentration (µg/L)
Paducah	Little Bayou Creek	124	0.3
	Ohio River	43,600	0.000004
Portsmouth	Little Beaver Creek	26	0.7
	Scioto River	2,240	0.0004
K-25	Poplar Creek	2,550	0.02
	Clinch River	94	0.0002

groundwater were obtained by assuming the surface value to be equal to the maximum concentration in water leaving each yard during a time interval of approximately 40 years. This duration corresponds to the time period for the no action alternative. Details on the methodology are given in Appendix C and Tomasko (1997b).

At the end of the no action period (2039), the concentrations of uranium in groundwater directly below the edge of the surface contamination at the Paducah, Portsmouth, and K-25 sites were estimated to be about 0.25, 0.1, and 0.6 µg/L, respectively (Table D.17), for a retardation factor of 5 (Tomasko 1997b). These concentrations are less than the EPA proposed drinking water MCL for uranium of 20 µg/L (EPA 1996). Maximum concentrations of 6, 5, and 7 µg/L would occur at the Paducah, Portsmouth, and K-25 sites, respectively, between 2070 and 2090 (Table D.17). For a retardation factor of 50 (relatively immobile uranium transport), maximum concentrations would be about 10 times less.

D.2.4.3 Soil

Estimated numbers of cylinder breaches assumed to occur under the no action alternative were used to calculate impacts to soil quality. Each breached cylinder was assumed to release a maximum of 1 lb/yr (0.45 kg/yr) for a maximum of 4 years. For soil, the only impacts would be to quality; there would be no impacts to topography, permeability, or erosion potential. Details on these calculations and methodology are presented in Appendix C and Tomasko (1997b).

At the Paducah site, the highest soil concentration of uranium would be 0.1 µg/g in about 2002 for a distribution coefficient (K_d) of 5 (relatively low sorption capacity). If the soil had a larger

TABLE D.17 Groundwater Concentrations for Continued Cylinder Storage for Two Soil Characteristics under the No Action Alternative[a]

Site/Parameter	X = 0 Concentration pCi/L	X = 0 Concentration µg/L	X = 0 Time at Maximum Concentration	X = 1,000 ft Concentration pCi/L	X = 1,000 ft Concentration µg/L	X = 1,000 ft Time at Maximum Concentration
Retardation Factor = 5						
Paducah						
Concentration at 40 years	0.07	0.25				
Maximum concentration	2	6.1	70 years	1.3	4.9	90 years
Portsmouth						
Concentration at 40 years	0.03	0.10				
Maximum concentration	1	5.1	80 years	1.1	4.1	96 years
K-25						
Concentration at 40 years	0.2	0.60				
Maximum concentration	2	7.3	60 years	1.5	5.7	80 years
Retardation Factor = 50						
Paducah						
Maximum concentration	0.2	0.7	585 years	0.1	0.5	770 years
Portsmouth						
Maximum concentration	0.1	0.5	670 years	0.1	0.4	860 years
K-25						
Maximum concentration	0.2	0.8	500 years	0.2	0.6	675 years

[a] Retardation factors describe how readily a contaminant such as uranium moves through the soil in groundwater. A retardation factor of 5 represents a case in which the uranium moves relatively rapidly in the soil; a retardation factor of 50 represents a case in which uranium moves slowly.

sorption capacity (K_d = 50), the maximum value would be 10 times greater (1.0 µg/g). At the Portsmouth site, the highest soil concentration of uranium would be 0.09 µg/g in about 2002 for a distribution coefficient of 5 (relatively low sorption capacity). If the soil had a larger sorption capacity (K_d = 50), the maximum value would be 10 times greater, 0.9 µg/g. At the K-25 site, the highest soil concentration of uranium would be 0.3 µg/g in about 2002 for a distribution coefficient of 5 (relatively low sorption capacity). If the soil had a larger sorption capacity (K_d = 50), the maximum value would be 3.0 µg/g. Even with the larger sorption, soil concentrations at the three sites would be below the recommended EPA guideline of 230 µg/g for residential soil and 6,100 µg/g for industrial soil (EPA 1995).

D.2.5 Socioeconomics

The impacts of continued storage on regional economic activity were estimated for a region of influence (ROI) at each of the three storage sites. Additional details regarding the assessment methodology are presented in Appendix C and Allison and Folga (1997).

Current storage activities at each site would likely have a small impact on socioeconomic conditions in the ROIs surrounding the three sites (see Chapter 3, Sections 3.1.8, 3.2.8, and 3.3.8). This is partly because a major proportion of expenditures associated with procurement for conducting continued storage activities would flow outside the ROI to other locations in the United States, thereby reducing the concentration of local economic effects of current storage activities at each site.

Slight changes in employment and income would occur in each ROI as a result of local spending derived from employee wages and salaries, local procurement of goods and services required to conduct continued storage activities, and other local investments associated with construction and operations. In addition to creating new (direct) jobs at each site, continued current storage would also create indirect employment and income in the ROI as a result of jobs and procurement expenditures at each site. Jobs and income created directly by continued storage, together with indirect activity in the ROI, would contribute slightly to a reduction in unemployment in the ROI surrounding each site. Minimal impacts would be expected on local population growth and, consequently, on local housing markets and local fiscal conditions.

The effects of continued cylinder storage activities on regional economic activity, measured in terms of employment and personal income, and on population, housing, and local public revenues and expenditures are discussed in Sections D.2.5.1 through D.2.5.3. Impacts are presented for each storage site during the peak year of construction and the peak year of operations. The potential impacts of continued cylinder storage at the three sites are shown in Table D.18.

D.2.5.1 Paducah Site

During the peak year for construction and reconstruction of cylinder yards, 20 direct jobs would be created at the site and 60 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 80 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $2.0 million of total income produced during the peak year. During the peak year of continued cylinder storage activities, 90 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, at a total income of $2.3 million. Continued storage activities would result in an increase of 0.005 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Construction activities would be expected to generate direct in-migration of 20 in the peak year (Table D.18). Additional indirect job in-migration would also be expected, bringing the total

TABLE D.18 Potential Socioeconomic Impacts of Continued Cylinder Storage under the No Action Alternative

Parameter	Paducah Site		Portsmouth Site		K-25 Site	
	Impacts from Construction[a]	Impacts from Operations[b]	Impacts from Construction[c]	Impacts from Operations[b]	Impacts from Construction[a]	Impacts from Operations[b]
Economic activity in the ROI						
Direct jobs	20	60	–	20	10	30
Indirect jobs	60	30	–	10	50	50
Total jobs	80	90	–	30	60	90
Income ($ million)						
Direct income	1.0	1.8	–	0.6	0.4	2.7
Total income	2.0	2.3	–	0.7	1.5	3.7
Population in-migration into the ROI	70	30	–	10	20	30
Housing demand						
Number of units in the ROI	20	10	–	0	10	10
Public finances						
Change in ROI fiscal balance (%)	0.0	0.0	–	0.0	0.0	0.0

[a] Impacts for peak construction year. Construction activities were assumed to occur over 4 years at the Paducah site and over 1 year at the K-25 site (Parks 1997).

[b] Impacts for peak year of operations. Duration of operations was assumed to be 41 years (1999-2039).

[c] No construction activities are planned for continued cylinder storage at the Portsmouth site.

number of in-migrants to 70 in the peak year. Continued cylinder storage activities would be expected to generate direct and indirect job in-migration of 30 in the peak year of operations and would result in an increase of 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for 20 additional rental housing units during the peak year of construction, representing an impact of 1.6% on the projected number of vacant rental housing units in the ROI (Table D.18). The demand for 10 additional owner-occupied housing units would be expected in the peak year of operations and would represent an impact of 0.3% on the number of vacant owner-occupied housing units.

During the peak year of construction, 70 persons would in-migrate into the ROI, which would lead to an increase of 0.04% over ROI-forecasted baseline revenues and expenditures (Table D.18). In the peak year of operations, 30 in-migrants would be expected, which would result in a 0.02% increase in local revenues and expenditures.

D.2.5.2 Portsmouth Site

During the peak year of continued cylinder storage activities, 20 direct jobs would be created at the site and 10 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 30 jobs would be created. Operations would also produce direct and indirect income in the ROI surrounding the site, at a total income of $0.7 million during the peak year. Continued cylinder storage operations would result in an increase of 0.001 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Continued cylinder storage activities would be expected to generate direct in-migration of less than 10 in the peak year (Table D.18). Additional indirect job in-migration would also be expected and would bring the total number of in-migrants to 10 in the peak year. Operations would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for less than 10 additional rental housing units during the peak year of construction, thus representing an impact of 0.1% on the projected number of vacant rental housing units in the ROI (Table D.18).

During the peak year of operations, 10 persons would in-migrate into the ROI, thereby leading to an increase that rounds to 0.0% over ROI-forecasted baseline revenues and expenditures (Table D.18).

D.2.5.3 K-25 Site

During the single year during which construction activities are planned at the K-25 site, 10 direct jobs would be created at the site and 50 additional jobs indirectly in the ROI (Table D.18) as a result of the spending of employee wages and salaries and procurement-related expenditures. Overall, 60 jobs would be created. Construction activity would also produce direct and indirect income in the ROI surrounding the site, with $1.5 million in income produced during the year. During the peak year of continued cylinder storage activities, 90 direct and indirect jobs would be created. Direct and indirect income would also be produced in the ROI, at a total income of $3.7 million. Continued cylinder storage activities would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in ROI employment from 1999 through 2039.

Construction activities would be expected to generate direct in-migration of 10 in the construction year (Table D.18). Additional indirect job in-migration would also be expected, bringing the total number of in-migrants to 20 in the peak year. Continued cylinder storage activities would be expected to generate direct and indirect job in-migration of 30 in the peak year of operations and would result in an increase of less than 0.001 percentage points in the projected baseline compound annual average growth rate in the ROI population from 1999 through 2039.

Continued cylinder storage activities would generate the demand for 10 additional rental housing units during the construction year and would represent an impact of 0.2% on the projected number of vacant rental housing units in the ROI (Table D.18). The demand for 10 additional owner-occupied housing units would be expected in the peak year of operations and would represent an impact of 0.1% on the number of vacant owner-occupied housing units.

During construction, 20 persons would in-migrate into the ROI, which would lead to an increase of less than 0.1% over ROI-forecasted baseline revenues and expenditures (Table D.18). In the peak year of operations, 30 in-migrants would be expected, which would result in a 0.01% increase in local revenues and expenditures.

D.2.6 Ecology

Impacts to ecological resources during continued cylinder storage would be expected to be negligible. Analysis of potential impacts was based on exposure to airborne contaminants or contaminants released to soil, groundwater, or surface water. Predicted concentrations of contaminants in environmental media were compared to benchmark values of toxic and radiological effects to assess impacts to terrestrial and aquatic biota. A detailed discussion of assessment methodology is presented in Appendix C.

At all three sites, atmospheric emissions of criteria pollutants from cylinder storage yard activities — including cylinder painting, cylinder relocation, and new yard construction (at the

Paducah and K-25 sites) — would be well below levels harmful to biota, and impacts to ecological resources would be negligible. (See Section D.2.3 for a discussion of air quality impacts and Appendix C for application of predicted values.)

The maximum annual average air concentration of HF at the site boundary, due to hypothetical cylinder breaches, would be very low, up to 0.08 µg/m^3 at the K-25 site and less for the other two sites (Section D.2.3). Resulting impacts to biota would be expected to be negligible. Potential impacts to ecological resources are shown in Table D.19.

Soil near the storage yards could become contaminated with uranium by surface runoff from the yards. Uptake of uranium-containing compounds can cause adverse effects to vegetation. The potential maximum uranium concentration in soil would be 1.0 µg/g at the Paducah site, 0.9 µg/g at the Portsmouth site, and 3.0 µg/g at the K-25 site (Section D.2.4.3). Because these estimated concentrations are below the lowest concentration known to produce toxic effects in plants, toxic effects on vegetation due to uranium uptake would not be expected (Table D.19).

Surface runoff from the storage yards would result in maximum (undiluted) uranium concentrations of 20, 19, and 52 µg/L (5.2, 4.8, and 13.4 pCi/L) at the Paducah, Portsmouth, and K-25 sites, respectively (Section D.2.4.1). Resulting dose rates to maximally exposed organisms in the nearest receiving surface water body at each site would be less than 0.016 rad/d, less than 2% of the dose limit of 1 rad/d for aquatic organisms, as specified in DOE Order 5400.5. These uranium concentrations are also considerably below 150 µg/L, which is the lowest concentration known to adversely affect aquatic biota. Therefore, impacts to aquatic biota would not be expected.

Surface runoff from the storage yards could infiltrate adjacent soil and become a source of groundwater contamination. Groundwater could discharge to the surface (such as in wetland areas) near the facility, thus exposing biota to contaminants. Groundwater concentrations of uranium near the storage yards could range up to 6.1, 5.1, and 7.3 µg/L at the Paducah, Portsmouth, and K-25 sites, respectively; uranium activity could range up to 2, 1, and 2 pCi/L, respectively (Section D.2.4.2). Resulting toxic effects and dose rates to maximally exposed organisms would be negligible. Resulting impacts to aquatic biota would therefore be negligible (Table D.19).

Facility accidents (Section D.2.2) could result in adverse impacts to ecological resources. The affected species and degree of impact would depend on a number of factors, such as location of the accident, season, and meteorological conditions.

D.2.7 Waste Management

The principal wastes expected to be generated by operations involving continued cylinder storage are low-level radioactive waste (LLW) and low-level mixed waste (LLMW). Impacts on waste management from wastes generated during the continued storage operations at the sites would be caused by the potential overload of waste treatment and/or disposal capabilities either at a site or

TABLE D.19 Potential Impacts to Ecological Resources from Continued Cylinder Storage under the No Action Alternative

Contaminant	Biota	Maximum Exposure	Effect
Paducah Site			
Hydrogen fluoride	Wildlife	0.009 µg/m^3	Negligible
Uranium in surface water	Aquatic	20 µg/L	Negligible
		5.2 pCi/L	Negligible
Uranium in groundwater	Aquatic	6.1 µg/L	Negligible
		1.6 pCi/L	Negligible
Uranium in soil	Plants	1.0 µg/g	Negligible
Portsmouth Site			
Hydrogen fluoride	Wildlife	0.01 µg/m^3	Negligible
Uranium in surface water	Aquatic	19 µg/L	Negligible
		4.8 pCi/L	Negligible
Uranium in groundwater	Aquatic	5.1 µg/L	Negligible
		2.1 pCi/L	Negligible
Uranium in soil	Plants	0.9 µg/g	Negligible
K-25 Site			
Hydrogen fluoride	Wildlife	0.08 µg/m^3	Negligible
Uranium in surface water	Aquatic	52 µg/L	Negligible
		13 pCi/L	Negligible
Uranium in groundwater	Aquatic	7.3 µg/L	Negligible
		1.9 pCi/L	Negligible
Uranium in soil	Plants	3.0 µg/g	Negligible

on a regional/national scale. Waste generated at the three sites from continued cylinder storage under the no action alternative are listed in Table D.20. Given the types and quantities of waste expected to be generated, there is little potential for impacts on regional or national waste treatment/disposal capabilities.

Only limited construction of additional facilities would be needed to support the operations involved in the continued storage and maintenance of cylinders. No waste management impacts resulting from construction-generated wastes would be expected.

The normal operations to maintain and store cylinders would consist of inspections, stripping and repainting of the cylinders, and disposal of scrap metal from breached cylinders that required emptying. These operations would generate two primary waste streams: (1) uranium-contaminated scrap metal LLW from breached cylinders and failed valves and (2) solid process residue LLMW from cylinder painting. In the event of cylinder failure, small amounts of additional LLMW could be generated due to releases from breached cylinders.

For all three current storage sites, the amount of LLW generated from continued storage would at most represent less than 1% of site LLW generation (see Appendix C, Section C.10.2). The maximum annual amount of LLW generated during the continued storage of cylinders at all three sites would represent less than 1% of the annual DOE LLW generation.

Continued storage would also generate LLMW at all three sites. At the Paducah site, stripping/painting operations would generate a maximum annual amount of 23 m^3 of LLMW, which

TABLE D.20 Waste Generated during Continued Cylinder Storage under the No Action Alternative

	Waste (m^3)	
Site	LLW[a]	LLMW[b]
Paducah	52	893
Portsmouth	23	418
K-25	10	157
Total (1999-2039)	85	1,468

[a] Contaminated scrap metal from empty cylinders.

[b] Inorganic process residues from cylinder painting.

would be about 20% of the site's total annual LLMW load, which represents a moderate impact to site waste management capabilities. At the Portsmouth site, the LLMW input would be less than 1% of the site load. At the K-25 site, continued cylinder storage would generate less than 1% of the total LLMW load at the Oak Ridge Reservation. Overall, the waste input resulting from continued cylinder storage would have negligible impacts on waste management capabilities at the Portsmouth and K-25 sites, but impacts from disposal of LLMW could have moderate impacts at the Paducah site. Impacts on national waste management capabilities would be negligible. The input of LLMW from continued cylinder storage at the three sites would represent less than 1% of the total nationwide LLMW load.

D.2.8 Resource Requirements

Material resources that could be consumed during continued cylinder storage include construction materials that could not be recovered or recycled, and materials consumed or reduced to unrecoverable forms of waste. Where construction is necessary, materials required could include concrete, sand, gravel, steel, and other metals. In general, none of the construction resources identified for continued cylinder storage are in short supply, and all would be readily available in the vicinity of the three sites. Energy resources during construction and operations would include the consumption of diesel fuel and gasoline for construction equipment and transportation vehicles. The anticipated utilities requirements would be within the supply capacities at each site. Detailed information relating to the methodology is presented in Appendix C.

Cylinder yard construction or reconstruction would occur only at the Paducah and K-25 sites. No reconstruction activities are anticipated at the Portsmouth site.

Continued cylinder storage would require materials such as 55-gal drums for containment of any generated waste, replacement cylinder valves for those found to be defective upon inspection, and diesel fuel and gasoline to operate equipment and on-site vehicles. In addition, two gallons of paint per cylinder would be required for cylinder painting. Potable water would be made available for the needs of the workforce.

Materials and utilities required for construction and operation activities for continued storage at the Paducah, Portsmouth, and K-25 sites are presented in Table D.21. The total quantities of commonly used construction materials are expected to be small compared to local sources. No strategic and critical materials are projected to be consumed for either construction or operations. Small amounts of diesel fuel and gasoline are projected to be used. The required material resources during operations would be readily available.

D.2.9 Land Use

No construction activities are planned for the Portsmouth site. Other than disturbances to narrow strips of land along the outer perimeters of existing yards, no additional land clearing would

TABLE D.21 Resource Requirements of Construction and Operations for Continued Cylinder Storage under the No Action Alternative

		Consumption during 1999-2039		
Materials/Resource	Unit	Paducah Site	Portsmouth Site	K-25 Site
Construction				
Solids				
Concrete	yd^3	20,000	0	8,000
Construction aggregate	yd^3	29,000	0	12,000
Special coatings	yd^2	90,000	0	36,000
Liquids				
Gasoline	gal	3,100	0	1,300
Diesel fuel	gal	18,000	0	7,300
Operations[a]				
Solids				
55-gal drums	each	104 – 109	50	18 – 20
Cylinder valves (1-in.)	each	9	4	2
Liquids				
Gasoline	gal/yr	3,400 – 4,500	1,600 – 1,700	700 – 1,000
Diesel fuel	gal/yr	8,600 – 13,600	4,100	1,500 – 2,600
Zinc-based paint	gal/yr	5,700 – 6,000	2,700	1,000 – 1,100

[a] Values reported as ranges generally correspond to varying resource requirements during years for which construction activities are planned.

be necessary at the Paducah site. Construction activities at Paducah would consist of modifications to existing yards; no new construction would occur outside the footprints of existing yards. Although no location has been chosen for a new storage yard at K-25, the areal requirement of 6.7 acres (2.7 ha) would be very small and represent less than 1% of the land available for development on the site. Because the yard would be located in an area already dedicated to similar use, immediate access to infrastructure and utility support would be possible with only minor disturbances to existing land use.

During continued cylinder storage operations, land-use impacts at the three sites would be negligible and limited to potential minor disruptions on land parcels contiguous to the existing yards. No impacts would be expected for off-site land use.

D.2.10 Cultural Resources

Impacts to cultural resources are not likely at the Paducah or Portsmouth sites during continued cylinder storage. The existing and proposed storage yards at Paducah are located in previously disturbed areas unlikely to contain cultural properties or resources eligible for the *National Register of Historic Places*. No new storage yards are proposed at Portsmouth, so no cultural resources would be affected. A new storage yard is proposed at the K-25 site; however, the exact location is unknown. Impacts might result if the storage yard was constructed on or near an eligible resource.

D.2.11 Environmental Justice

The analysis of potential environmental justice impacts resulting from continued cylinder storage is based on the conclusions drawn in the assessment of impacts on human health (Sections D.2.1 and D.2.2) and a review of environmental impacts presented in discussions of other technical areas (Sections D.2.3 through D.2.10) such as air quality, water quality and soils, socioeconomics, and ecological resources. The analysis of health effects included an examination of risks to the general public associated with normal facility operations and accidents. A detailed description of the mapping procedures, screening criteria, calculational methods, and demographic sector analysis is presented in Appendix C, Section C.8.

Events occurring after 2039 could not be included in the analysis of potential environmental justice impacts because the composition of the population residing within 50 miles (80 km) of a site cannot be projected with accuracy over the long term. Current minority and low-income population proportions for each site were assumed out to the year 2039.

A review of potential human health impacts (Sections D.2.1 and D.2.2) indicated that no high and adverse human health effects or impacts would be expected from continued storage of cylinders at the Paducah, Portsmouth, and K-25 sites. Therefore, although minority and low-income populations reside within 50 miles (80 km) of the sites, no disproportionate impacts would be expected. The distributions of minority and low-income population census tracts within a 50-mile (80-km) radius of each site are shown in Appendix C, Figures C.1 through C.3. Screening criteria limits (Appendix C, Section C.8) for radiological and chemical sources under normal operations and accident conditions were not exceeded, and the risk of fatalities from operations and accidents from 1999 through 2039 would be considerably below one. Radiological releases from normal operations at the three sites would result in annual average doses to the MEI residing outside the facilities that would be considerably below the DOE regulatory limit of 100 mrem/yr for members of the public. Chemical impacts from routine operations under continued storage at all three sites would result in MEI hazard indices well below 1. Additionally, accidental chemical releases would not result in any expected fatalities or expected adverse human health effects for the general public (when considering risk, i.e., the product of the potential number of persons affected and the probability of the accident occurring).

A review of impact assessments for other technical areas (Sections D.2.3 through D.2.10) indicated that few or no impacts would be expected from continued storage of cylinders at any of the sites. Projected air emissions from construction activities and operations would be below federal and state regulatory limits and no impacts to water quality or soils are anticipated. Consequently, no segment of the population, including minorities or persons of low-income, would experience disproportionate impacts.

D.2.12 Other Impacts Considered But Not Analyzed in Detail

Other impacts that could potentially occur as a result of continued storage of depleted UF_6 cylinders at the three current storage sites include impacts to the visual environment (e.g., aesthetics), recreational resources, and noise levels, as well as impacts associated with decontamination and decommissioning of the storage yards. These impacts, although considered, were not analyzed in detail because the impacts would be negligibly small or consideration of the impacts would not contribute to differentiation among the alternatives and therefore would not affect the decisions to be made in the Record of Decision to be issued following publication of this PEIS.

D.3 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE BASED ON UNCERTAINTIES IN CORROSION CONTROL

Under the no action alternative, it was assumed that cylinders would be painted every 10 years and that the paint would effectively stop any further corrosion of the cylinders (see introduction to this appendix). To address uncertainty in both the effectiveness of the painting in controlling further corrosion and uncertainties in the future painting schedule, a conservative assessment was made of the impacts assuming that painting would have no effect on corrosion. Under this assumption and using historical data from the three sites, the number of breaches that would occur at each site as a function of time were estimated (Lyon 1997). These conservative estimates indicate that the number of breaches that could occur prior to 2039 would be about 400 at Paducah, 74 at Portsmouth, and 210 at K-25 (see Appendix B).

If no credit were taken for corrosion reduction through painting, and if storage was continued at the three current storage sites indefinitely, calculations indicate that uranium releases from breaches occurring at the Paducah site prior to about the year 2020 could result in a sufficient amount of uranium in the soil column to bring the groundwater concentration of uranium to 20 μg/L in the future (about 2100) (Tomasko 1997a). The cylinders would have to undergo uncontrolled corrosion (without painting) until about 2050 at Portsmouth, and until about 2025 at the K-25 site before the same groundwater concentration guideline of 20 μg/L would be a concern. Again, the groundwater concentration would not actually reach 20 μg/L at these sites until about 2100 or later.

Also, if no credit were taken for corrosion reduction through painting, air quality concerns might arise. Calculations indicate that breaches occurring at the K-25 site by around the year 2020 could result in maximum 24-hour average HF concentrations at the site boundary approximately equal to 2.9 µg/m^3 (3.5 ppb). This level corresponds to the primary standard for the State of Tennessee. For comparison, the maximum estimated 24-hour average HF concentration at the Paducah and Portsmouth sites through the year 2039 would be 2 µg/m^3 and 0.6 µg/m^3, considerably below the 2.9 µg/m^3 level (the State of Kentucky primary standard for HF is much higher [816 µg/m^3 maximum 24-hour average]; the State of Ohio does not have standards for HF).

A painting program for the cylinders, designed to control further corrosion, has been initiated at the three sites. Therefore, the assumption of uncontrolled corrosion is not a reasonable assumption. The painting program is expected to eliminate or substantially reduce the corrosion of cylinders at the sites. DOE will continue to monitor its cylinders and is committed to maintain the safety basis of continued cylinder storage. If the conditions became substantially different from what is assumed under the no action alternative, DOE would take the appropriate action(s) to maintain the safety basis.

D.4 POTENTIAL IMPACTS OF CONTINUED CYLINDER STORAGE FOR THE ACTION ALTERNATIVES

For the action alternatives considered in this PEIS — long-term storage as UF_6, long-term storage as uranium oxide, use as uranium oxide, use as uranium metal, and disposal as uranium oxide — continued storage could be necessary for some portion of the DOE-generated cylinders at the current storage sites through approximately 2028. This 30-year storage period would correspond to the period during which construction of conversion, long-term storage, and/or disposal facilities would occur and during which the cylinders would be transported from the current locations to the processing locations. For analyses in this PEIS, the cylinder removal period was assumed to take place between 2009 and 2028; the number of cylinders at each site would decrease by 5% annually during that time.

Potential environmental impacts associated with continued cylinder storage for the action alternatives were assessed with essentially the same methodology used to estimate impacts for the no action alternative (see Section D.2 and Appendix C). Through the year 2008, the number of maintenance activities (such as inspections, yard reconstruction, and painting) was assumed to be the same as for the no action alternative (Parks 1997). From 2009 through 2028, the number of maintenance activities was assumed to decrease by 5% annually, to correspond to the reduction in cylinder inventory that would be occurring. Impacts associated with maintenance activities (e.g., radiation doses to involved workers) would, therefore, generally be reduced for the action alternatives.

A key difference between the assessment of continued storage impacts conducted for the action alternatives and the assessment conducted for the no action alternative was in the assumptions made regarding potential numbers of breached cylinders. Because of impending cylinder movement or content transfer, cylinder yard improvement and cylinder painting might not occur at the same rate under the action alternatives as they would under the no action alternative. Because the painting schedule that would be followed under the action alternatives is not known, and to present reasonable upper bound estimates of impacts, no credit was taken for the effectiveness of cylinder yard improvements and painting in reducing cylinder corrosion rates. Therefore, the number of hypothetical cylinder breaches assumed for the action alternatives was estimated by assuming that painting and improved storage conditions were not effective in arresting continued corrosion of the cylinders (i.e., assuming that corrosion continued at historical rates; see Appendix B) and by assuming that the population of cylinders at each site was decreasing at an annual rate of 5% between the years 2009 and 2028. These assumptions led to a higher number of assumed breaches for continued storage under the action alternatives than under the no action alternative, even though the number of years of storage would be lower. The assumptions for releases of uranium and HF from breached cylinders, as well as for methods to estimate water and soil impacts, were identical to those used for the assessment of impacts for the no action alternative. However, the outcome of the increased number of assumed cylinder breaches was a slightly higher estimate of impacts on groundwater, air quality, and human health and safety for the action alternatives, although the estimated impacts are still within applicable standards or guidelines (see Table D.1). The impacts of continued cylinder storage under the action alternatives for the various technical areas of interest are discussed in Sections D.4.1 through D.4.11. Assessment methods are described in Appendix C and in Section D.2.

D.4.1 Human Health — Normal Operations

D.4.1.1 Radiological Impacts

Estimated radiation doses and latent cancer risks for each of the three storage sites are presented in Tables D.22 and D.23. Long-term radiological impacts (based on groundwater contamination) are provided in Table D.24.

D.4.1.1.1 Paducah Site

During the continued cylinder storage period, the average annual collective dose for involved workers would be about 15 person-rem/yr for an average of 23 workers, assuming the workers work 5 hours per day in the cylinder yard. The individual dose for involved workers would average 650 mrem/yr for this period of time. The maximum dose for noninvolved workers would be less than 0.3 mrem/yr, well below the regulatory limit of 10 mrem/yr. For the general public, the maximum dose would be approximately 0.1 mrem/yr, with 0.03 mrem/yr from airborne pathways and 0.07 mrem/yr from groundwater pathways.

Long-term radiation exposure after year 2028 from use of contaminated groundwater would result in a maximum dose of 1.3 mrem/yr, which is a small fraction of the DOE dose limit of 100 mrem/yr for the general public.

TABLE D.22 Radiological Doses from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Annual Dose to Receptor					
	Involved Workers[a]		Noninvolved Workers[b]		General Public	
Site	Average Individual Dose (mrem/yr)	Collective Dose (person-rem/yr)	MEI Dose[c] (mrem/yr)	Collective Dose[d] (person-rem/yr)	MEI Dose[e] (mrem/yr)	Collective Dose[f] (person-rem/yr)
Paducah	650	15	0.26	0.012	0.031 (< 0.072)	0.017
Portsmouth	450	6.0	0.057	0.00040	0.017 (< 0.0051)	0.0017
K-25	260	3.0	0.17	0.0031	0.37 (< 0.085)	0.017

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual dose and collective dose for the worker population. The reported values are averages over the time period 1999-2028. Radiation doses to individual workers would be monitored by a dosimetry program and maintained below applicable standards, such as the DOE administrative control limit of 2,000 mrem/yr.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest dose. The reported values are the maximums over the time period considered.

[d] The reported collective doses are averages over the time periods considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest dose. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective dose was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.23 Latent Cancer Risks from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Annual Risk of Latent Cancer Fatality to Receptor					
	Involved Worker[a]		Noninvolved Worker[b]		General Public	
Site	Average Individual Risk (risk/yr)	Collective Risk (fatalities/yr)	MEI Risk[c] (risk/yr)	Collective Risk[d] (fatalities/yr)	MEI Risk[e] (risk/yr)	Collective Risk[f] (fatalities/yr)
Paducah	3×10^{-4}	6×10^{-3}	1×10^{-7}	5×10^{-6}	2×10^{-8} ($< 7 \times 10^{-9}$)	8×10^{-6}
Portsmouth	2×10^{-4}	2×10^{-3}	2×10^{-8}	2×10^{-7}	8×10^{-9} ($< 5 \times 10^{-10}$)	8×10^{-7}
K-25	1×10^{-4}	1×10^{-3}	7×10^{-8}	1×10^{-6}	2×10^{-7} ($< 8 \times 10^{-9}$)	9×10^{-6}

[a] Involved workers are those workers directly involved with the handling of materials. Impacts are presented as average individual risk and collective risk for the worker population. The reported values are averages over the time period 1999-2028.

[b] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. Exposures of noninvolved workers would result from airborne emissions of UO_2F_2 due to hypothetically breached cylinders. The exposure pathways considered included inhalation, external radiation, and incidental ingestion of soil.

[c] The MEI for the noninvolved workers was assumed to be at the on-site (outside storage yards) location that would yield the largest risk. The reported values are the maximums over the time period considered.

[d] The reported collective risks are averages over the time period considered. Population size of the noninvolved workers was assumed to be about 2,000 for Paducah, 2,700 for Portsmouth, and 3,500 for K-25.

[e] The MEI for the general public was assumed to be located off-site at a point that would yield the largest risk. The reported values are the maximums over the time period considered and are the results of exposures from inhalation, external radiation, and ingestion of plant foods, meat, milk, soil (all consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders and from drinking surface water (consequence of discharge of contaminated runoff water to a surface water body). Values within parentheses are the potential maximum doses from using contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[f] Collective risk was estimated for the population within a radius of 50 miles (80 km) around the three sites. The reported values are averages over the time period considered. The off-site populations are 500,000 persons for Paducah, 605,000 for Portsmouth, and 877,000 for K-25. Exposure pathways considered were inhalation, external radiation, and ingestion of plant foods, meat, milk, and soil (consequences of airborne emissions of UO_2F_2) due to hypothetically breached cylinders.

TABLE D.24 Long-Term Radiological Impacts to Human Health from Continued Cylinder Storage under the Action Alternatives[a,b]

Storage Location	Impact to MEI of General Public: Radiation Dose[c] (mrem/yr)	Impact to MEI of General Public: Latent Cancer Risk[c] (risk/yr)
Paducah site	0.13 – 1.3	$6 \times 10^{-8} – 7 \times 10^{-7}$
Portsmouth site	0.021 – 0.21	$1 \times 10^{-8} – 1 \times 10^{-7}$
K-25 site	0.077 - 0.64	$4 \times 10^{-8} – 3 \times 10^{-7}$

[a] Long-term impacts correspond to the time after the year 2028.

[b] Long-term impacts would be caused by the potential use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock. Contamination of groundwater would result from releases from hypothetically breached cylinders and the resulting infiltration of UO_2F_2 to the deeper soils, eventually reaching the groundwater (UO_2F_2 is the product of UF_6 reacting with moisture in air).

[c] Radiation doses and latent cancer risks are expressed as ranges, which would result from different transport speeds of uranium in soil. The reported values are the maximum values that would occur after 2028, assuming no mitigation action was taken.

D.4.1.1.2 Portsmouth Site

During the cylinder storage period (1999-2028), the average annual collective dose for involved workers would be 6.0 person-rem/yr for approximately 14 workers, resulting in an average individual dose of 450 mrem/yr. The doses for the MEIs of noninvolved workers and members of the general public would be less than 0.06 and 0.02 mrem/yr, respectively, from airborne emission of UO_2F_2. Additional exposure of the general public could be caused by use of contaminated groundwater; the maximal dose would be about 0.005 mrem/yr by the end of the cylinder storage period. The radiation exposure of involved workers would be much less than the regulatory limit of 5,000 mrem/yr; exposure of noninvolved workers and members of the general public would be quite small compared with the regulatory limits of 10 mrem/yr for airborne emissions and 100 mrem/yr for all exposure pathways for the general public.

Long-term radiation exposure after the year 2028 from the use of contaminated groundwater would result in a maximum dose of 0.21 mrem/yr.

D.4.1.1.3 K-25 Site

Radiation exposures of involved workers at the K-25 site would be less than those at the Paducah and Portsmouth sites because fewer cylinders would be managed at the K-25 site. During continued cylinder storage, involved workers would receive an average dose of 260 mrem/yr from performing cylinder maintenance activities. The average annual collective dose for involved workers would be 3.0 person-rem/yr for approximately 12 workers. Radiation exposures of noninvolved workers and members of the general public would be less than 0.17 and 0.37 mrem/yr, respectively, from airborne emission of UO_2F_2. The dose for the general public MEI would be greater than that for the noninvolved worker MEI because of the close proximity from the assumed emissions point to the site boundary. Potential radiation exposure from the use of contaminated groundwater would result in a dose of less than 0.081 mrem/yr at the end of this period.

Long-term radiation exposure after the year 2028 from the use of contaminated groundwater would result in a maximal dose of 0.64 mrem/yr.

D.4.1.2 Chemical Impacts

Chemical impacts associated with continued cylinder storage could result primarily from exposure to uranium compounds and HF released from hypothetical cylinder breaches. Estimated impacts for each of the three storage sites are given in Table D.25. The highest hazard quotients result when the use of contaminated groundwater is considered in addition to exposures through inhalation, soil ingestion, and surface water ingestion (i.e., maximum hazard quotient of 0.17 at the Paducah site). Adverse health effects would not be expected from exposure to chemical contaminants associated with continued cylinder storage (that is, the estimated hazard indices would all be less than the threshold value of 1).

D.4.2 Human Health — Accident Conditions

The assessment of impacts conducted for potential accidents associated with continued cylinder storage under the action alternatives was similar to that for the no action alternative (Section D.2.2) in that the same accidents were considered and the consequences of those accidents would be the same. However, because the duration of continued cylinder storage under the action alternatives is 11 years shorter than that assessed for the no action alternative (i.e., 30 years assumed for the action alternatives compared with 41 years assumed for the no action alternative), the risk of these accidents occurring would therefore be somewhat lower under the action alternatives.

TABLE D.25 Chemical Impacts to Human Health from Continued Cylinder Storage under Normal Operations for the Action Alternatives

	Impacts to Receptor			
	Noninvolved Workers[a]		General Public[b]	
Site/Time Period	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)	Hazard Index[c] for MEI	Population Risk[d] (ind. at risk/yr)
Paducah site				
1999-2028	1.6×10^{-3}	–	5.2×10^{-3} (9.0×10^{-3})	–
Long-term impacts[e]	NA[f]	–	0.02 – 0.17	–
Portsmouth site				
1999-2028	3.9×10^{-5}	–	3.0×10^{-3} (6.4×10^{-4})	–
Long-term impacts[e]	NA	–	0.003 – 0.03	–
K-25 site				
1999-2028	1.1×10^{-3}	–	6.5×10^{-2} (1.1×10^{-2})	–
Long-term impacts[e]	NA	–	0.01 – 0.08	–

[a] Noninvolved workers are individuals who work on-site but not within the cylinder storage yards. The MEI for the noninvolved worker was assumed to be at the on-site (outside storage yards) location that would yield the largest exposure. Exposures would result from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders; the exposure pathways considered included inhalation and incidental ingestion of soil.

[b] The MEI for the general public was assumed to be located off-site at the point that would yield the largest exposure. Results reported are the maximum values for the time period considered and would result from exposure via inhalation; ingestion of soil (resulting from airborne emissions of UO_2F_2 and HF from hypothetically breached cylinders); and drinking surface water (consequence of the discharge of contaminated runoff water to a surface water body). Potential impacts during the storage period 1999-2028 (values within parentheses) were also evaluated from the use of contaminated groundwater for drinking, irrigating plant foods and fodder, and feeding livestock.

[c] The hazard index is an indicator for potential health effects other than cancer; a hazard index greater than 1 indicates a potential for adverse health effects and a need for further evaluation.

[d] Calculation of population risk is not applicable when the corresponding hazard index for the MEI is less than 1.

[e] Long-term impacts would result from using contaminated groundwater.

[f] NA = not applicable; workers were assumed not to ingest groundwater.

D.4.2.1 Radiological Impacts

The accidents that might be associated with continued cylinder storage under the action alternatives are identical to those addressed under the no action alternative. See Section D.2.2.1 for the discussion of potential human health impacts associated with radiological exposures from accidental releases.

D.4.2.2 Chemical Impacts

The accidents that might be associated with continued cylinder storage under the action alternatives are identical to those addressed under the no action alternative. See Section D.2.2.2 for the discussion of potential human health impacts associated with chemical exposures from accidental releases.

D.4.2.3 Physical Hazards

The activities considered in calculating the physical hazards associated with continued cylinder storage were routine cylinder inspections, ultrasonic inspections, valve monitoring and maintenance activities, cylinder relocations, cylinder yard construction or reconstruction, cylinder painting, and patching and content transfers of breached cylinders. The annual labor requirements and the corresponding fatality and injury risks to all workers for these activities were estimated to be less than 1 (0.07) for the total three-site fatality risk and about 90 injuries for the total three-site injury risk (see Table D.26).

D.4.3 Air Quality

The assessment of air quality impacts from construction, relocating cylinders, and painting cylinders conducted for the no action alternative would also be applicable for the action alternatives because the assessment was based on maximum annual impacts (i.e., the same construction activities were assumed, as well as the same levels of relocating and painting cylinders during the initial years of continued storage). Potential impacts on air quality from these activities are discussed in Section D.2.3.

The estimated HF emissions for the action alternatives would differ from those for the no action alternative because different numbers of breached cylinders were assumed (see Appendix B). The numbers of hypothetical breaches and estimated resulting HF concentrations at the three current storage sites are given in Table D.27. The estimated 0.27 $\mu g/m^3$ maximum 24-hour average HF concentration for the Paducah site is considerably below the Kentucky primary annual standard for HF of 400 $\mu g/m^3$ (0.5 ppm). The estimated 2.7 $\mu g/m^3$ maximum 24-hour average HF concentration for the K-25 site is below the Tennessee 24-hour average standard of 2.9 $\mu g/m^3$.

TABLE D.26 Estimated Impacts to Human Health from Physical Hazards under Continued Cylinder Storage for the Action Alternatives[a,b]

Impacts to All Workers (Involved and Noninvolved)[c]							
Fatality Incidence				Injury Incidence			
Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites	Paducah Site	Portsmouth Site	K-25 Site	Total, 3 Sites
0.03	0.02	0.02	0.07	41	26	23	90

[a] Potential impacts are based on continued storage activities, which would include routine inspections, ultrasonic inspections, valve monitoring and maintenance, cylinder relocations, cylinder yard construction and reconstruction, cylinder painting, and patching and content transfers for breached cylinders for the time period 1999-2028.

[b] Risk estimates include reconstruction of L-, M-, N-, and P-yards at Paducah and construction of a new yard at K-25.

[c] Injury and fatality rates used in the calculations were taken from National Safety Council (1995).

TABLE D.27 Estimated Number of Breached Cylinders, Maximum HF Emissions, and Average Maximum HF Concentrations at the Existing Storage Sites for the Action Alternatives

Site	Maximum Number of Breaches Starting in a Single Year	Maximum Total Number of Active Breaches in a Single Year	Maximum HF Concentration ($\mu g/m^3$) 24-Hour Average	Maximum HF Concentration ($\mu g/m^3$) Annual Average
Paducah	4	16	0.27	0.03
Portsmouth	1	4	0.14	0.015
K-25	3	8	2.7	0.34

D.4.4 Water and Soil

D.4.4.1 Surface Water

The estimated numbers of cylinder breaches assumed to occur during continued cylinder storage for the action alternatives are given in Appendix B. These estimates were used to calculate potential impacts to surface water quality. Each breached cylinder was assumed to release a maximum of 4 lb (1.8 kg) of uranium over 4 years; additional details on the methodology used to evaluate the impacts are given in Appendix C and Tomasko (1997b).

The estimated maximum uranium concentrations in runoff water leaving the yards would be about 121, 25, and 130 µg/L (31, 6, and 34 pCi/L) for the Paducah, Portsmouth, and K-25 sites, respectively. These concentrations would occur in about the year 2018. After leaving the yards, the contaminated runoff was assumed to flow without loss to the nearest surface water, where it would mix and be diluted. For average flow conditions, the dilution would be large enough that the maximum concentrations would be less than 2 µg/L (0.5 pCi/L) for all three sites (see Table D.28). This concentration is less than the EPA proposed drinking water MCL for uranium of 20 µg/L, used here for comparison. The contaminated water would then mix with water in the Ohio River, Scioto River, or Clinch River, which would result in even greater dilution. Because of this mixing, impacts to the major rivers would not be measurable.

TABLE D.28 Maximum Uranium Concentrations in Surface Waters for Continued Cylinder Storage under the Action Alternatives

Site	Receiving Water	Dilution Factor	Maximum Concentration (µg/L)
Paducah	Big Bayou Creek	124	1.7
	Ohio River	43,600	0.00002
Portsmouth	Little Beaver Creek	26	1
	Scioto River	2,240	0.0005
K-25	Poplar Creek	2,550	0.05
	Clinch River	94	0.0005

D.4.4.2 Groundwater

Methods for estimating groundwater impacts were the same as those used for the no action alternative (Section D.2.4.2); however, a larger number of cylinder breaches was assumed to occur. Conservative estimates of the concentrations of uranium in groundwater were obtained by assuming the surface value to be equal to the maximum concentration in water leaving each yard during a time interval of approximately 20 years; this time interval corresponds to the time over which the concentration in surface water would be higher than half of its maximum value.

At the end of the time period considered for the action alternatives (1999-2028), the concentration of uranium in groundwater directly below the edge of the surface contamination at the Paducah, Portsmouth, and K-25 sites is estimated to be about 1.1, 0.09, and 1.3 µg/L (0.3, 0.02, and 0.3 pCi/L), respectively, for a retardation factor of 5 (Table D.29) (Tomasko 1997b). These concentrations are less than the proposed EPA drinking water MCL for uranium of 20 µg/L, used here for comparison (EPA 1996).

Maximum concentrations of about 20, 4, and 9 µg/L (5, 1, and 3 pCi/L) would occur between the years 2070 and 2080 at Paducah, Portsmouth, and K-25, respectively, assuming a retardation factor of 5. The maximum concentration would only equal the EPA proposed drinking water guideline at Paducah; this guideline is not directly applicable because the groundwater directly at the boundary of the nearest surface water is unlikely to be used as a drinking water source. For a retardation factor of 50 (relatively immobile uranium transport), maximum concentrations would be about 10 times less. These concentrations would occur between the years 2500 and 2700.

Assuming a retardation factor of 5 and a distance of 1,000 ft (300 m) from the edge of the source area, the maximum concentration of uranium would range from about 9 µg/L (3 pCi/L at the K-25 site to 16 µg/L (4 pCi/L) at the Paducah site. For less mobile conditions (retardation of 50), the maximum concentrations would be about 10 times less.

D.4.4.3 Soil

Maximum uranium concentrations in soil for a distribution coefficient of 50 (relatively high sorption capacity) would range from 1.2 µg/g for the Portsmouth site to 6.5 µg/g for the K-25 site. If the soil had a lower sorption capacity (distribution coefficient of 5), the soil concentrations would be 10 times lower. These maximum soil concentrations associated with continued cylinder storage under the action alternatives are much lower than the recommended EPA guideline levels of 230 µg/g for residential soil or 1,000 µg/g for industrial soil (EPA 1995).

TABLE D.29 Groundwater Concentrations for Continued Cylinder Storage for Two Soil Characteristics under the Action Alternatives[a]

	X = 0			X = 1,000 ft		
	Concentration		Time to Maximum Concentration	Concentration		Time to Maximum Concentration
Site/Parameter	pCi/L	µg/L		pCi/L	µg/L	
Retardation Factor = 5						
Paducah						
Concentration at 30 years	0.28	1.1				
Maximum concentration	5.2	20	> 70 years	4.0	16	> 70 years
Portsmouth						
Concentration at 30 years	0.02	0.09				
Maximum concentration	0.8	3.5	> 70 years	0.7	2.8	> 70 years
K-25						
Concentration at 30 years	0.33	1.3				
Maximum concentration	2.5	9.4	> 70 years	2.0	7.7	> 70 years
Retardation Factor = 50						
Paducah						
Maximum concentration	0.5	2.1	> 500 years	0.4	1.6	> 500 years
Portsmouth						
Maximum concentration	0.08	0.4	> 500 years	0.07	0.3	> 500 years
K-25						
Maximum concentration	0.3	1.1	> 500 years	0.2	0.8	> 500 years

[a] Retardation factors describe how readily a contaminant such as uranium moves through the soil in groundwater. A retardation factor of 5 represents a case in which the uranium moves relatively rapidly in the soil; a retardation factor of 50 represents a case in which uranium moves slowly.

D.4.5 Socioeconomics

The methods used to assess socioeconomic impacts of continued cylinder storage for the action alternatives were the same as those used for the no action alternative (Section D.2.5). Impacts are presented in Table D.30. Construction impacts would be identical to those estimated for the no action alternative because all construction would take place during the time period 1999-2008, when identical activities are assumed. For K-25, the estimated impacts from operations under the action alternatives are slightly higher than those estimated for the no action alternative, primarily because of the increased number of cylinder breaches assumed, which would require increased levels of activities for repairs, thus leading to increased employment. Under the action alternatives,

TABLE D.30 Potential Socioeconomic Impacts of Continued Cylinder Storage under the Action Alternatives

Parameter	Paducah Site		Portsmouth Site		K-25 Site	
	Impacts from Construction[a]	Impacts from Operations[b]	Impacts from Construction[c]	Impacts from Operations[b]	Impacts from Construction[a]	Impacts from Operations[b]
Economic activity in the ROI						
Direct jobs	20	60	–	20	10	40
Indirect jobs	60	30	–	10	50	70
Total jobs	80	90	–	30	60	110
Income ($ million)						
Direct income	1.0	1.7	–	0.5	0.4	3.8
Total income	2.0	2.2	–	0.6	1.5	5.1
Population in-migration into the ROI	70	30	–	10	20	30
Housing demand						
Number of units in the ROI	20	10	–	0	10	10
Public finances						
Change in ROI fiscal balance (%)	0.0	0.0	–	0.0	0.0	0.0

[a] Impacts for peak construction year. Construction activities were assumed to occur over 4 years (1999-2002) at the Paducah site and over 1 year (1999) at the K-25 site.

[b] Impacts for peak year of operations. Duration of operations was assumed to be 30 years (1999-2028).

[c] No construction activities are planned for continued cylinder storage at the Portsmouth site.

continued storage activities would still have a negligible impact on socioeconomic conditions in the ROIs surrounding the three sites.

D.4.6 Ecology

For continued cylinder storage under the action alternatives, the maximum annual average HF concentrations would be 0.009 µg/m^3, 0.015 µg/m^3, and 0.081 µg/m^3 for the Paducah, Portsmouth, and K-25 sites, respectively (Section D.4.3). Resulting impacts to biota would be expected to be negligible. Contamination of soils near the storage yards by surface runoff could result in maximum uranium concentrations of 6.1 µg/g at the Paducah site, 1.2 µg/g at the Portsmouth site, and 6.5 µg/g at the K-25 site (Section D.4.4). The predicted concentrations for the Paducah and K-25 sites are approximately the same as the lowest uranium concentration reported to produce toxic effects in plants (5 µg/kg). The extent of vegetation affected would be restricted to the area of surface runoff from the yards. Therefore, impacts to vegetation would be expected to be negligible to low. Surface runoff from the storage yards would have a maximum uranium concentration of 121 µg/L (31 pCi/L) at the Paducah site, 25 µg/L (6 pCi/L) at the Portsmouth site, and 130 µg/L (34 pCi/L) at the K-25 site (Section D.4.4). Resulting impacts to maximally exposed organisms in the nearest receiving surface water body at each site would be expected to be negligible. Uranium concentrations in groundwater would be considerably less and resulting impacts to aquatic biota would be negligible.

Uranium concentrations in groundwater following the cylinder removal period would be very low, and long-term impacts to aquatic biota would not be expected. Contaminants associated with cylinder storage would not occur in other environmental media following the cylinder removal period.

D.4.7 Waste Management

As for the no action alternative, the principal wastes that are expected to be generated during continued cylinder storage are uranium-contaminated scrap metal from breached cylinders and failed valves, assumed to be LLW, and solid process residue from cylinder painting, assumed to be LLMW. The amounts of these waste types estimated to be generated for continued cylinder storage under the action alternatives is given in Table D.31. The annual amount of LLW generated would be less than 2% of site LLW generation for all three sites. The maximum annual amount of LLW generated during continued cylinder storage at all three sites would represent less than 1% of the annual DOE LLW generation.

For the Portsmouth and K-25 sites, the annual amount of LLMW generation would be less than 1% of site LLMW generation. However, for the Paducah site, the annual amount of LLMW generated during the initial years of evaluation, when painting of the entire inventory was assumed

TABLE D.31 Waste Generated during Continued Cylinder Storage under the Action Alternatives

	Waste (m^3)	
Site	LLW[a]	LLMW[b]
Paducah	792	440
Portsmouth	350	204
K-25	206	45
Total (1999-2028)	1,348	689

[a] Contaminated scrap metal from empty cylinders.

[b] Inorganic process residues from cylinder painting.

to occur (23 m^3/yr), would represent about 20% of the site's total annual LLMW load, a moderate impact on site waste management capabilities. The input of LLMW from continued storage would represent less than 1% of the total nationwide LLMW load.

Overall, the waste input resulting from the continued storage of cylinders under the action alternatives would have negligible impacts on waste management capabilities at the Portsmouth and K-25 sites. Impacts from disposal of LLMW could have moderate impacts at the Paducah site. Impacts on national waste management capabilities would be negligible.

D.4.8 Resource Requirements

Resource requirements for continued cylinder storage under the action alternatives are summarized in Table D.32. The resource requirements for construction would be identical to those for the no action alternative. The upper end of the range of annual requirements shown in Table D.32 generally corresponds to the upper end of the range estimated for the no action alternative; these requirements represent the early years of continued cylinder storage when some construction activities are planned. The lower end of the range of annual resource requirements is lower than the lower values for the no action alternative because maintenance of the decreasing cylinder inventory would require fewer resources.

The total quantities of commonly used construction materials needed for continued storage under the action alternatives are expected to be small compared with local sources. No strategic and critical materials are projected to be consumed for either construction or operations. Small amounts

TABLE D.32 Resource Requirements of Construction and Operations for Continued Cylinder Storage under the Action Alternatives

		Consumption during 1999-2028		
Materials/Resource	Unit	Paducah Site	Portsmouth Site	K-25 Site
Construction				
Solids				
Concrete	yd^3	20,000	0	8,000
Construction aggregate	yd^3	29,000	0	12,000
Special coatings	yd^2	90,000	0	36,000
Liquids				
Gasoline	gal	3,100	0	1,300
Diesel fuel	gal	18,000	0	7,300
Operations[a]				
Solids				
55-gal drums	each	53 – 109	26 – 50	10 – 18
Cylinder valves (1-in.)	each	4 – 9	2 – 4	1 – 2
Liquids				
Gasoline	gal/yr	2,000 – 4,500	810 – 1,600	450 – 1,000
Diesel fuel	gal/yr	4,300 – 13,600	2,100 – 4,100	800 – 2,600
Zinc-based paint	gal/yr	2,900 – 6,000	1,400 – 2,700	470 – 1,000

[a] Values reported as ranges generally correspond to varying resource requirements during years for which construction activities are planned.

of diesel fuel and gasoline are projected to be used. The required material resources during operations would appear to be readily available.

D.4.9 Land Use

Construction activities assumed for continued storage under the action alternatives are identical to those assumed for the no action alternative. Therefore, potential land-use impacts would be the same as those discussed in Section D.2.9.

D.4.10 Cultural Resources

Potential impacts to cultural resources under the action alternatives would be identical to those discussed in Section D.2.10.

D.4.11 Environmental Justice

Because no screening criteria limits for radiological and chemical sources under normal operations were exceeded under the action alternatives, no disproportionate impacts to minority and low-income populations would be associated with normal operations for continued cylinder storage. The assessment of impacts for potential accidents associated with continued cylinder storage under the action alternatives is similar to that for the no action alternative (Section D.2.11) in that the same accidents were considered and the consequences of those accidents would be the same. However, because the duration of continued cylinder storage under the action alternatives is 11 years shorter than that assessed for the no action alternative (i.e., 30 years assumed for the action alternatives compared with 41 years assumed for the no action alternative), the risk of these accidents occurring is somewhat lower. However, the conclusion that no disproportionate impacts would be associated with continued cylinder storage under the no action alternative is still applicable for the action alternatives because risks are lower for these alternatives.

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